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NORTHWEST REGION, PACIFIC NORTHWEST WATER LABORATORY

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LIQUID WASTE DISPOSAL IN THE LAVA TERRANE OF CENTRAL OREGON

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27 Abstract

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The disposal wells are concentrated in the Bend, Redmond, and Madras areas. They range from a few feet to over 400 feet in depth. Large quantities of ground water underlie these areas and are being developed for domestic water supplies. The injection of liquid waste into disposal wells and the construction of deep uncased water wells create a threat to water quality. The prevention of further drain well construction and the casing of all deep water wells are recommended. (WRSIC Abstract)

Abstractor: Jack E. Sceva

Institution: Federal Water Quality Administration

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LIQUID WASTE DISPOSAL
IN THE
LAVA TERRANE OF CENTRAL OREGON

Prepared by

Jack E. Sceva
Technical Projects Branch

Report No. FR-4

U. S. Department of the Interior
Federal Water Pollution Control Administration
Northwest Region
Pacific Northwest Water Laboratory
Corvallis, Oregon

May 1968

ABSTRACT

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LIQUID WASTE DISPOSAL IN THE LAVA TERRANE OF CENTRAL OREGON

I. INTRODUCTION

A. Initiation of Study

The Federal Water Pollution Control Act, as amended, authorizes the Federal Water Pollution Control Administration to conduct studies and surveys concerning problems of water pollution that are confronting any State, interstate agency, community, municipality, or industrial plant. Such studies and surveys must be requested by a State water pollution control agency.

In January 1966, the Oregon State Sanitary Authority requested the Federal Water Pollution Control Administration to investigate the "environmental hazards associated with the disposal of sewage wastes in deep lava sinkholes in the Deschutes Valley Oregon". The project was approved for study by the Federal Water Pollution Control Administration, and work commenced in June 1966.

B. Purpose

The study was planned to include an initial feasibility study phase that was expected to last about one year. During this phase, basic information about waste, waste disposal practices, and the occurrence, chemical character, and movement of ground water would be obtained for use in preparing a plan

and cost estimate for a full-scale study of the problem. If the full-scale study could be expected to provide sufficient information to justify its cost, it would be staffed and continued.

The geologic, hydrologic, and water-quality information gathered during the feasibility study indicated that ground-water pollution was not yet a serious problem in the Middle Deschutes Basin and that any full-scale study would be extremely expensive as numerous deep test wells would be required. The information gained in a full-scale investigation would be extremely helpful in the development of the ground-water resources of the area, but would not aid materially in eliminating the threat of water pollution. It was, therefore, decided that further study would not be undertaken at this time.

C. Scope of Study

1. Location of Study Area

The Deschutes River is a northward flowing stream that drains a large part of the eastern slope of the Cascade Mountains in Oregon. It is tributary to the Columbia River about 90 miles east of Portland. Its drainage basin, which is the second largest in the State, exceeds 10,000 square miles. The location is shown on Figure 1.

The project area was confined to the west-central part of the drainage basin. The population of the project area is

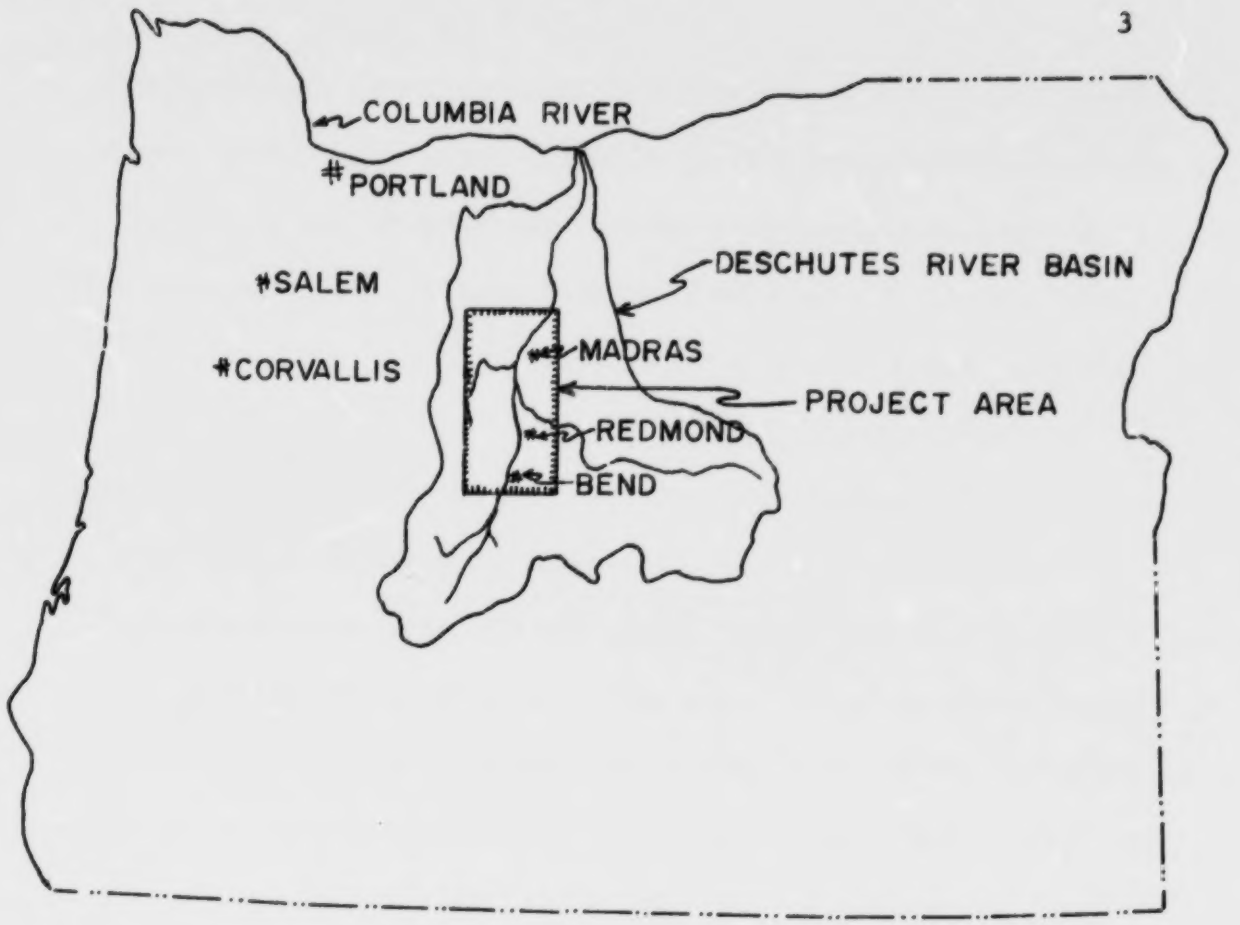

FIGURE 1.--MAP OF OREGON SHOWING THE LOCATION OF THE DESCHUTES RIVER BASIN AND THE PROJECT AREA

about 25,000 and is concentrated in three towns, Bend (13,200), Redmond (3,900), and Madras (1,800). These three towns served as centers of concentrated study. The geology, occurrence of ground water, and the waste disposal practices of each area are described separately in this report.

2. Description of Study

The information collected during the feasibility study was to aid in planning and to provide information useful in determining sites, depths, and costs for test wells to monitor ground-water quality. Information on many of the existing water wells was collected to define the water table and subsurface geology. Water samples were collected from numerous wells and springs to provide information on the quality of water.

After it was decided that a full-scale investigation would be too expensive, this report was prepared to provide the basic data on the geology, ground water, and liquid waste disposal operations in the Middle Deschutes Basin. The report also contains some recommendations as to how to reduce the threat of ground-water pollution. The basic data is given in a separate appendix.

3. Acknowledgments

The help and assistance of the Tri-County Health Department, the City of Bend Engineering Department and the U. S. Forest Service are gratefully acknowledged. The information contributed by water well and disposal well contractors and well owners is also appreciated.

II. SUMMARY

A. Findings

The following are some of the general findings that relate to the occurrence and movement of ground water and waste disposal operations.

1. A large part of the study area is underlain with porous and permeable lava flows that at most places extend from land surface to depths of 50 to 100 feet.

2. The surficial lava flows are at most places underlain by layers of sand, gravel, pumice, and cinders.

3. The regional water table ranges from 500 to 600 feet below land surface at Bend, 250 to 300 feet at Redmond, and 300 to 400 feet at Madras. Some perched ground-water zones occur in all three areas.

4. The ground-water resources of the study area constitute the chief source of water supply still available for development.

5. The regional water table in the Bend and Redmond areas slopes generally northward, and ground water moves in that direction.

6. A barrier of rocks having a low permeability transects the Deschutes River Basin near Madras. This barrier forces all of the ground water to be discharged into the river system.

Over one million acre-feet a year is discharged by springs in the Crooked River Canyon north of Redmond.

7. Ground water from the regional water reservoir is being developed from deep wells located throughout the study area. Many of these are uncased wells, having only short sections of surface casing.

8. Most of the ground water sampled in the study area was of good chemical quality.

9. The chief method of sewage disposal in Bend, Redmond, and Madras is by the discharge of septic tank effluent down drilled disposal wells.

10. Most of the disposal wells in Bend and Redmond are relatively shallow, and they discharge waste into cracks and joints in the surficial lava flows.

11. Disposal wells in Madras are generally deeper than those at Bend and Redmond, and they discharge waste into a lava interbed in the Madras Formation.

12. The liquid wastes in the study area are chiefly domestic wastes from individual septic tanks. There are no large quartities of industrial waste being discharged to the ground at this time.

B. Recommendations

1. As more and more deep water wells are being constructed in the Middle Deschutes Basin and as more and more waste

is being discharged to the ground each year, all deep water wells should be adequately cased and pressure grouted so that they will not provide avenues for pollutants to enter the regional ground-water reservoir.

2. As it will be only a matter of time before the continued and uncontrolled discharge of waste into disposal wells will create a ground-water pollution problem, the further construction of disposal wells should be discontinued.

3. The abandonment and plugging of existing disposal wells should be encouraged. This can be best accomplished by promoting the construction of municipal sewers and sewage treatment plants at Bend, Redmond, and Madras.

III. DESCRIPTION OF STUDY AREA

A. Geologic Setting

The Bend-Redmond area is a broad, flat plain lying between the Cascade Mountains on the west and the Ochoco Mountains on the east. This plain is dissected by the deep canyons of the Deschutes, Crooked, and Metolius Rivers. The elevation at Bend is approximately 3600 feet above sea level; Redmond is 3000 feet and Madras is 2200 feet.

This broad plain is mantled by extensive basaltic lava flows. These flows are commonly referred to as the "rimrock lavas" as they form the cliffs that border most of the canyons in the area. The rimrock lavas serve as the chief rock unit for the disposal of liquid waste in the Bend-Redmond area and range from about 50 to 150 feet in thickness.

The rimrock flows generally overlie a formation which is composed chiefly of layers of pumice, ash, conglomerate, sandstone, mudflow deposits, and contains some interbedded lava flows. This formation, which has been named the Madras Formation, is the primary source of ground water in the Middle Deschutes Basin. In the Deschutes River Canyon north of Redmond, the Madras Formation exceeds 700 feet in thickness with its base unexposed.

At some places, the Madras Formation overlies the Columbia River Basalt Formation. This formation is a series of basaltic lava flows that underlies thousands of square miles in Oregon and

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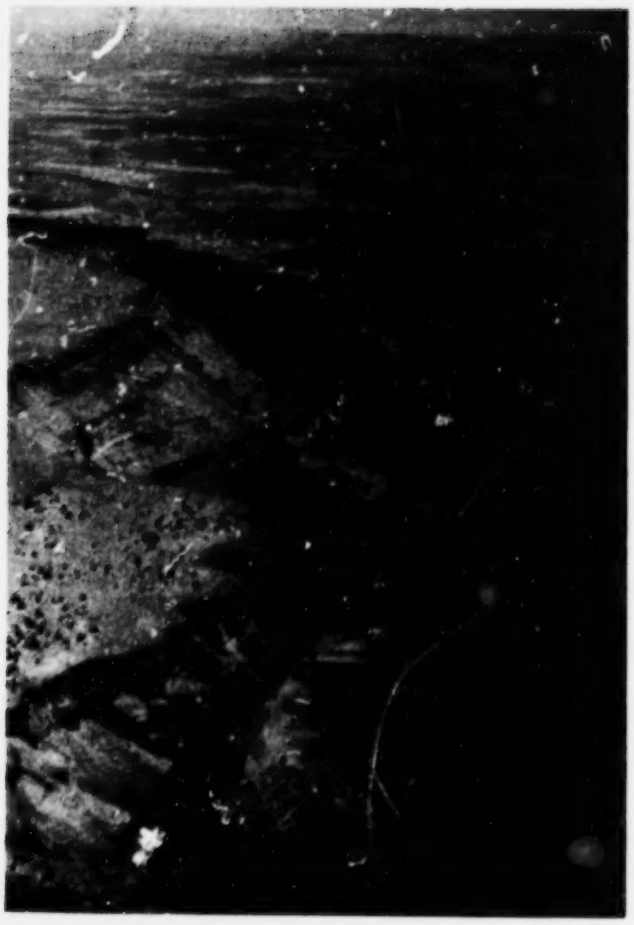
Washington and serves as an important source of ground water. The areal extent of the Columbia River Basalt in the Middle Deschutes Basin is not known, but it does crop out in the Crooked River Canyon near Trail Crossing north of Redmond. Both the Madras Formation and the Columbia River Basalt overlie the John Day Formation. The John Day Formation is a sedimentary unit composed chiefly of tuff. It has a low permeability and generally does not transmit ground water.

After the deposition of the Madras Formation and the rimrock lavas, a period of erosion resulted in the cutting of deep canyons by the Deschutes, Crooked, and Metolius Rivers in the area north of Redmond. This period of canyon-cutting was followed by another period of volcanic activity. A tremendous volume of very fluid basaltic lava originating southeast of Bend flowed northward and spilled into the Crooked River Canyon. This lava, which has been called the "intracanyon basalt" flowed downstream for more than thirty miles and accumulated to depths of over 400 feet. A similar but smaller accumulation of basalt also partially filled the Deschutes River Canyon northwest of Redmond. During Recent time, the Crooked and Deschutes Rivers eroded new canyons into the intracanyon basalt as terraces (Figure 2).

The John Day Formation transects the Deschutes River Basin near Madras and forms a subsurface barrier that prevents the downstream movement of ground water. This barrier forces all of the

FIGURE 2



A. VIEW OF THE CROOKED RIVER CANYON NEAR MADRAS. INTRACANYON BASALT FORMS THE BROAD TERRACE.

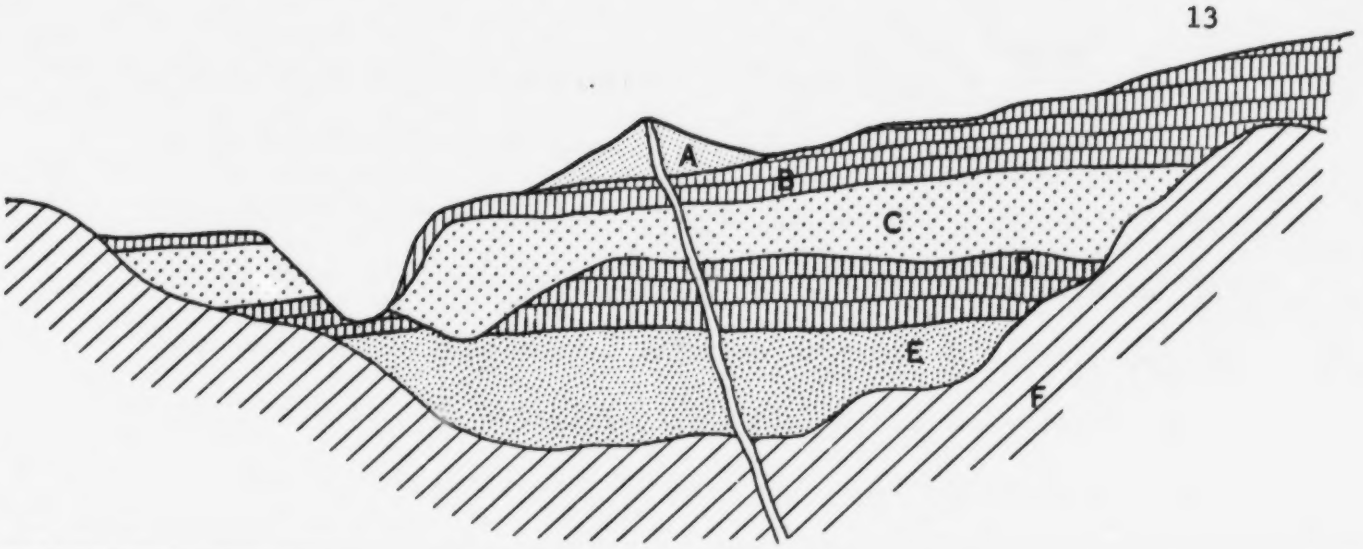
B. WALL OF CROOKED RIVER CANYON SHOWING LAVAS IN THE MADRAS FORMATION. INTRACANYON BASALT SHOWN AT RIGHT.

ground water to discharge into the river system where it continues its journey to the Columbia River in the flow of the Deschutes River. Figure 3 is a diagrammatic section showing the various rock units in the Middle Deschutes Basin and their water-bearing properties.

B. Hydrology and Water Supply

The Upper Deschutes River south of Bend is a slow, meandering stream that winds its way across an old lake bed which formed when the ancestral Deschutes River was impounded by lava flows originating at Lava Butte. These flows blocked the course of the Deschutes River and forced it to erode a new channel across a ridge of volcanic rock. This new channel is now a series of falls and rapids that have been named Benham Falls. A large amount of ground water discharges into the Deschutes River upstream from Benham Falls, but a well recently constructed by the U. S. Forest Service at Lava Butte, a few miles to the east, has a static water level slightly lower than the lip of Benham Falls. This water level indicates that not all of the ground water moving northward in this area is discharged into the Deschutes River and that some ground water is bypassing Benham Falls. The Deschutes River looses water in the reach below Benham Falls where it flows adjacent to the Lava Butte lavas.

At Bend, almost the entire flow of the Deschutes River is diverted into irrigation canals, including the Central Oregon



Designation in Figure	Unit Name	Character	Water-bearing Characteristics
A	Quaternary pyroclastic deposits	Chiefly cinders associated with cinder cones.	Rocks of this unit are generally well drained and not sources of ground water. Where saturated they are capable of yielding large supplies of ground water.
B	Quaternary lavas	Chiefly basaltic lava flows associated with Newberry Crater, and volcanic eruptions in the Cascade Range.	Contains numerous porous lava flows. At most places are well drained and are unproductive. Where they are saturated, they are capable of yielding moderate to large supplies of ground water.
C	Madras formation	Chiefly stratified layers of sand, silt, ash, pumice with some gravel lenses. Contains some interbedded lava flows.	This formation is in large part fine grained and not a productive aquifer. At places it contains permeable lenses of gravel that are capable of yielding moderate supplies of ground water. Some of the interbedded volcanic rocks are permeable and are capable of yielding large supplies of ground water.
D	Columbia River basalt	Series of basaltic lava flows.	Contact zones between individual lava flows serve as aquifers. This formation is generally capable of yielding moderate to large supplies of ground water.
E	John Day formation	A sedimentary formation composed of silt, sand, and volcanic ash.	The fine grained character of this formation precludes it from being a productive source of ground water.
F	Clarno formation and older rocks undifferentiated	Chiefly consolidated sedimentary rocks, volcanic rocks and associated pyroclastics.	All of these rocks are believed to be of low permeability and not capable of furnishing more than meager supplies of ground water.

FROM UNPUBLISHED REPORT - OREGON STATE ENGINEER

FIGURE 3. --MAJOR ROCK UNITS IN THE DESCHUTES RIVER BASIN

Irrigation Canal which supplies irrigation water in the Redmond area and the North Unit Canal which supplies irrigation water to the Madras area. These irrigation canals also serve as sources of domestic water for a large number of people. The Central Oregon Irrigation Canal is operated periodically throughout the year to allow people to fill their cisterns. The City of Madras utilizes the North Unit Canal for its municipal water supply during the summer months. The use of irrigation ditches for domestic water supplies has resulted in the passage of laws that prevent the discharge of any waste into irrigation ditches and canals. (See Oregon Revised Statutes 449.545 through O.R.S. 449.567.)

The Deschutes River from just below Benham Falls to below Cline Falls is a perched stream. The water table at Bend lies some 500 feet below river level. Below Cline Falls the water table intersects the river. Figure 4 shows the approximate direction of ground-water movement in the Middle Deschutes Basin, and Plates 1, 2, and 3 show the approximate elevation of the water table.

The barrier of impermeable rock that transects the Deschutes River Basin near Madras causes all of the ground water to discharge into the river system. Over 1,400 cfs discharges into the Crooked River Canyon, and somewhat smaller amounts discharge in the Deschutes and Metolius Canyons. Some of this discharge now occurs directly into Lake Chinook, the reservoir impounded behind Round Butte Dam.

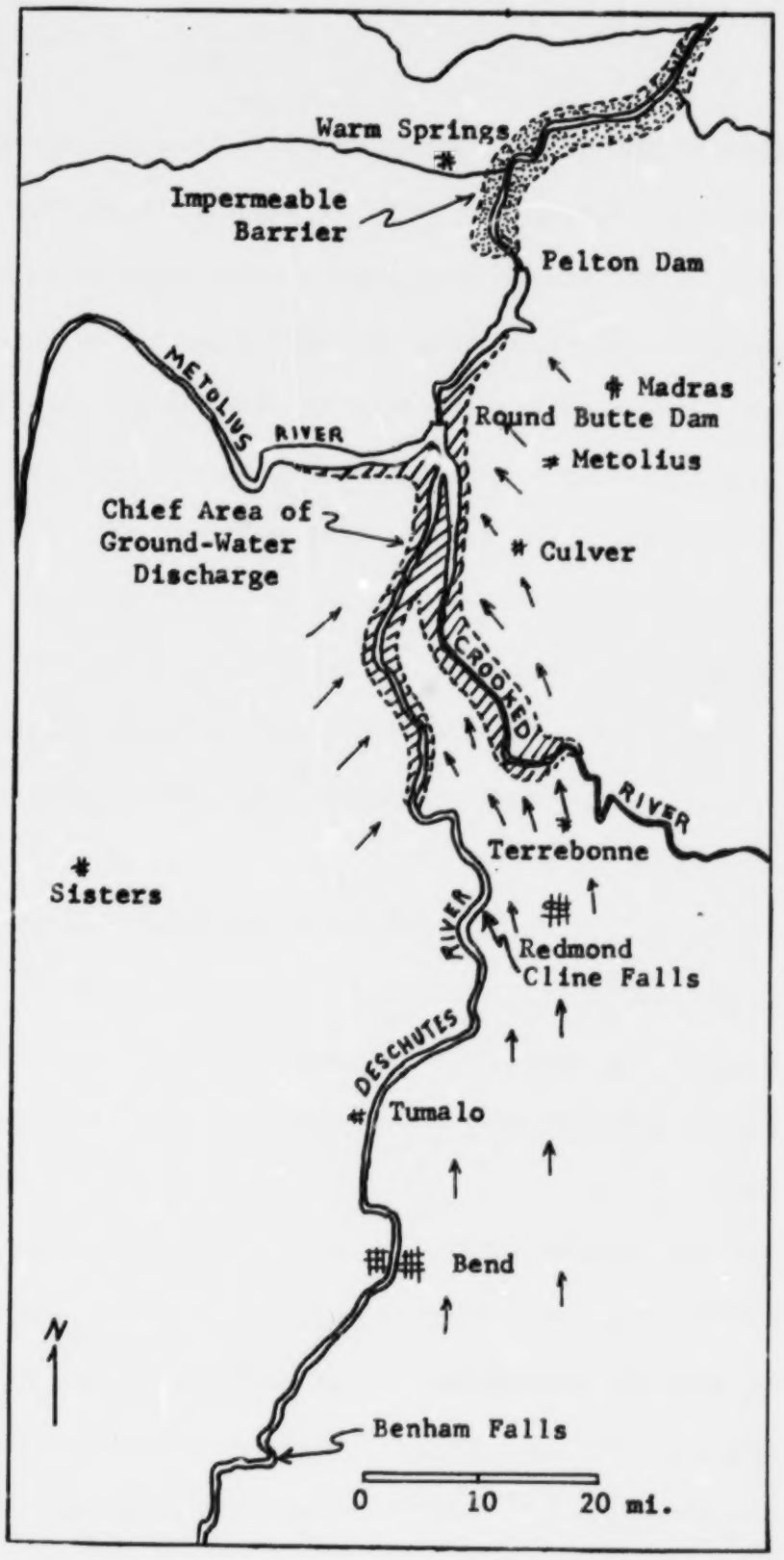


FIGURE 4.--MAP OF THE PROJECT AREA SHOWING CHIEF AREA OF GROUND-WATER DISCHARGE.
ARROWS INDICATE GENERAL DIRECTION OF GROUND WATER-MOVEMENT.

The flow of the Crooked River upstream from the Crooked River Canyon is very low during the month of August. Therefore, the flow measured in the Canyon near Culver represents chiefly ground water discharge. Figure 5 shows the mean August flow for this station from 1918 to 1960. The rise in flow during this 42-year period is attributed to a gradual buildup of ground-water storage caused by irrigation. The entire water yield of the Deschutes River Drainage Basin is believed to be in the flow of the Deschutes River as it passes Pelton Dam northwest of Madras. The August flow of the Deschutes River in this area, which is almost entirely ground-water discharge, was about 4,000 cfs prior to the construction of Pelton Dam.

As such a large part of the flow of the Deschutes River comes directly from ground-water discharge, any operation that could materially alter the quality of the ground-water resources would eventually have a direct bearing on the quality of the Deschutes River system.

Most of the available surface water supplies in the area south of Redmond have been appropriated and most new water supplies will depend upon the development of ground-water. The City of Bend obtains its municipal supply from Tumalo Creek but is currently planning the construction of a municipal well southwest of town. The City of Redmond obtains its water from the Deschutes River and Madras has two wells that are used when canal water is not available.

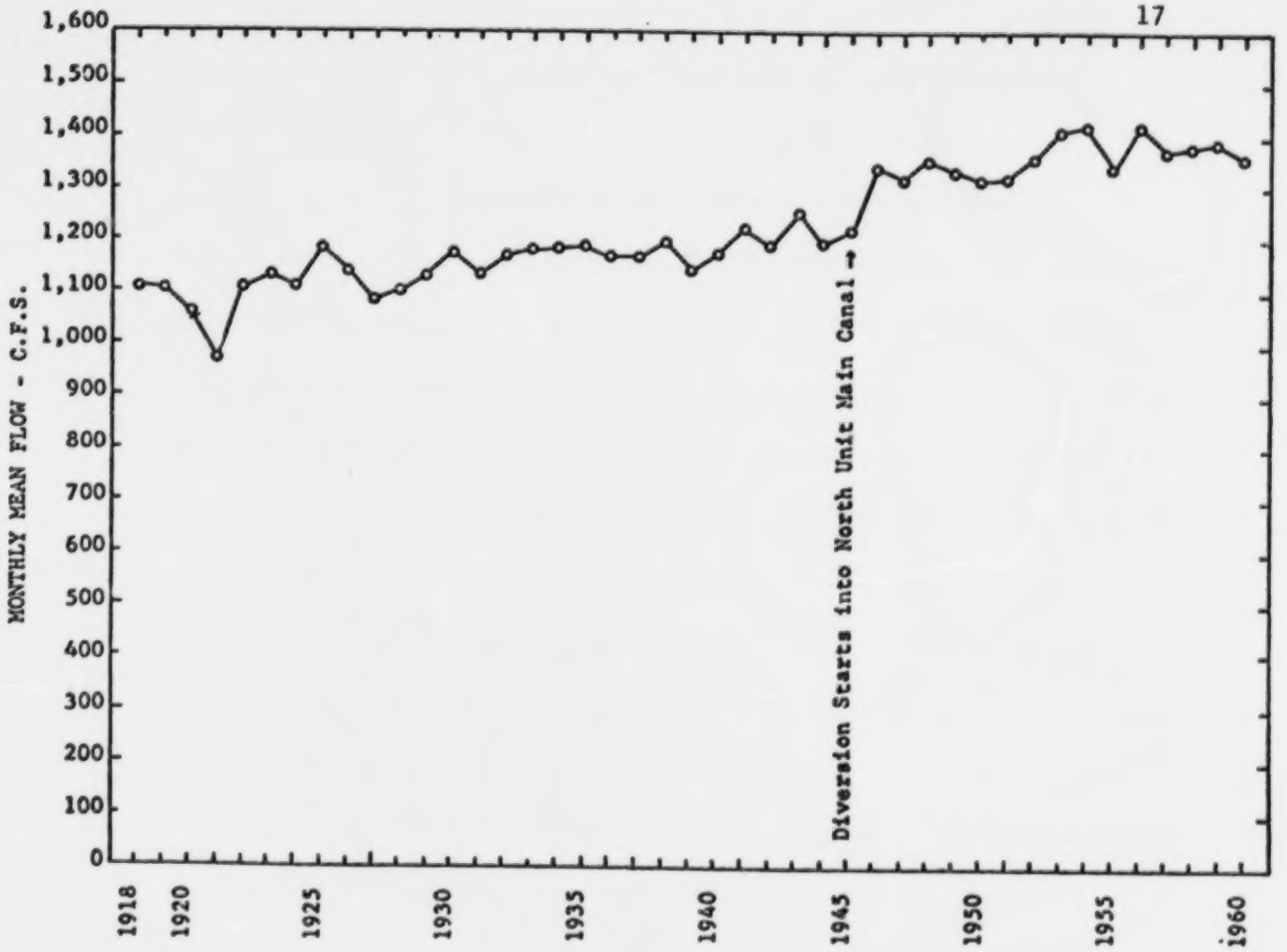


FIGURE 5. --MONTHLY MEAN AUGUST FLOW FOR THE CROOKED RIVER NEAR CULVER, OREGON
1918-60 (DATA FROM USGS)

C. Liquid Waste Disposal Practices

1. Sewage Disposal

The typical domestic sewage disposal system in Bend, Redmond, and Madras consists of an individual septic tank and a drilled disposal well. Many of the rural systems rely on septic tanks and conventional drain fields. The septic tank is either metal or concrete and is placed in a pit that has been excavated with the help of several charges of dynamite.

The disposal well is usually 6 to 8 inches in diameter and is completed with several feet of casing at the top to keep the soil zone from caving into the hole. The top of the casing is generally a foot or so beneath the surface and is covered with a concrete slab, hub cap, or some easily available cover. A drain pipe from the septic tank extends one to two inches into the disposal well through a hole in the side of the surface casing. A diagram of a typical disposal well system is shown on Figure 6, and the construction and installation of a septic tank is shown on Figure 7.

Disposal wells vary greatly in depth, averaging about 60 feet in Bend and Redmond and well over 100 feet in the Madras area. At the present time disposal wells are being constructed for about $3.00 per foot, plus a setup fee for the well drilling machine. The construction of a sewage disposal well is shown on Figure 8A.

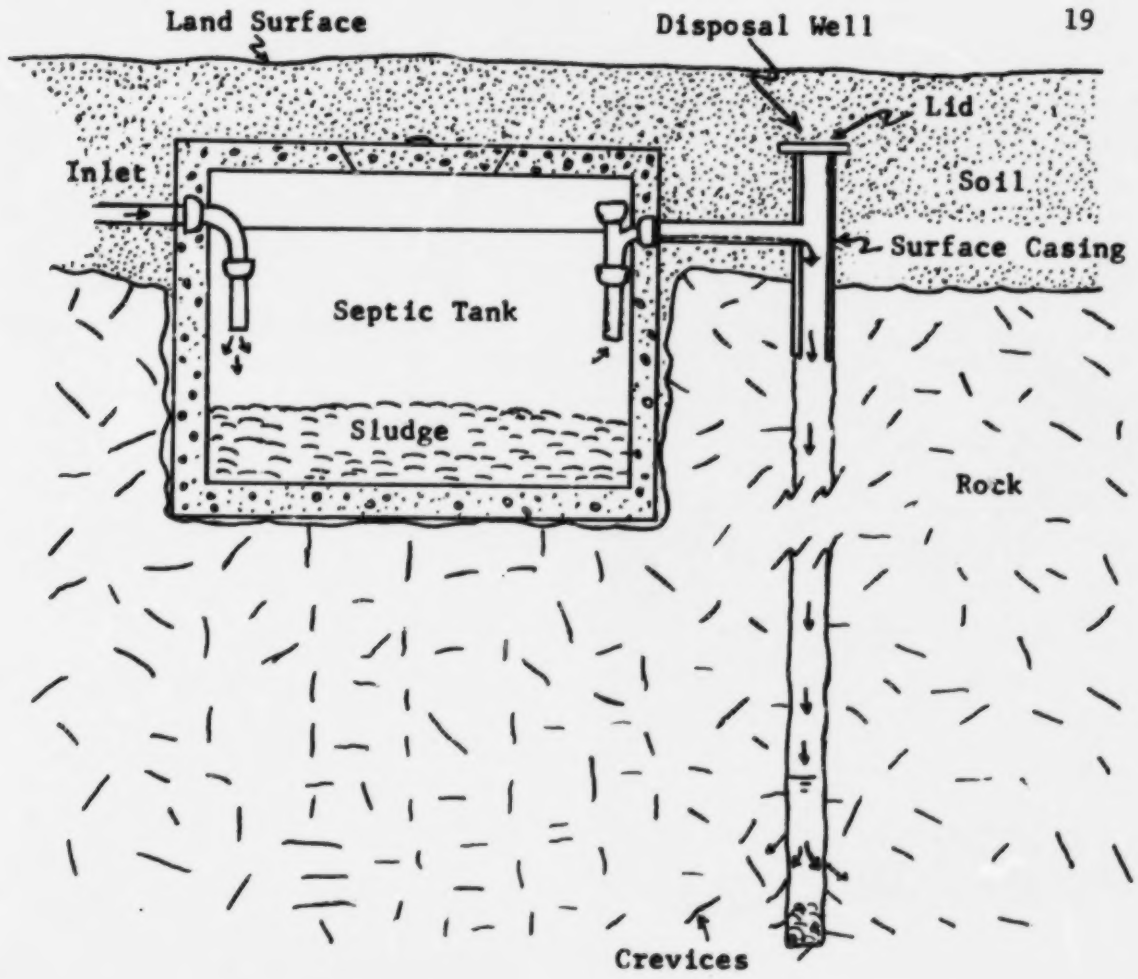


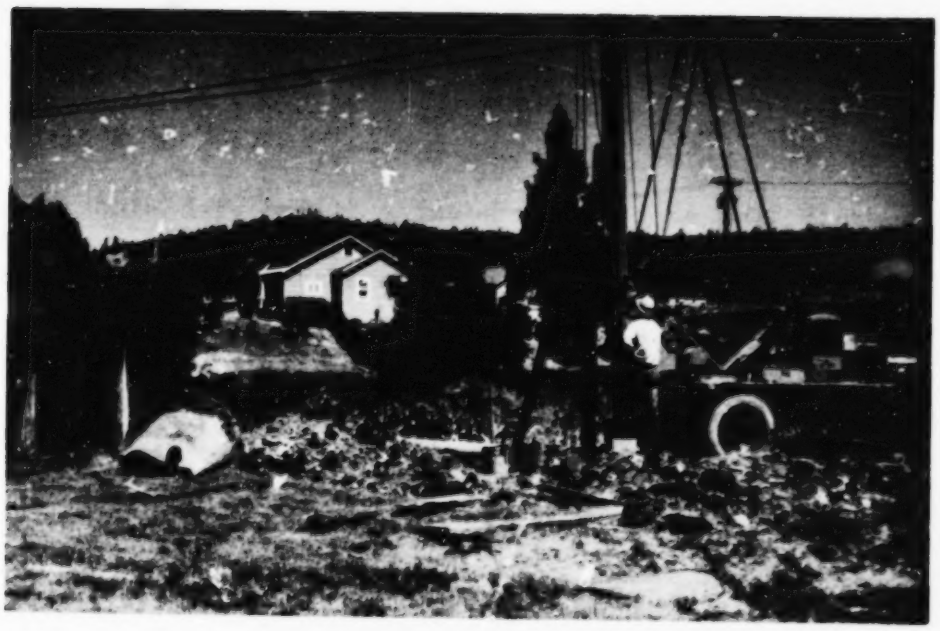
FIGURE 6. --DIAGRAM OF A TYPICAL DOMESTIC SEWAGE DISPOSAL SYSTEM IN THE MIDDLE DESCHUTES BASIN

FIGURE 7

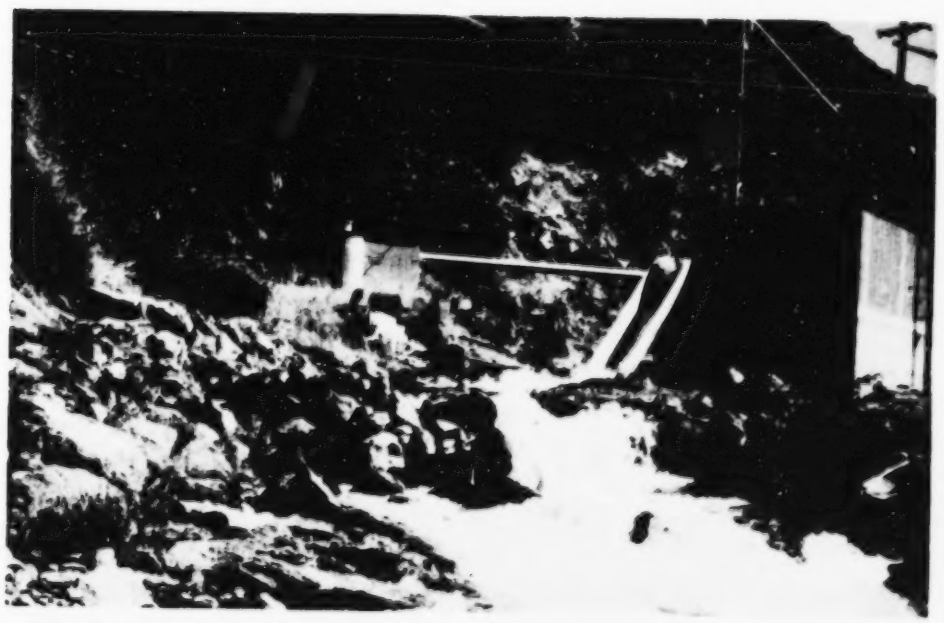
A. PIT BEING EXCAVATED IN LAVA FOR SEPTIC TANK. ROCK HAS JUST BEEN FRACTURED BY DYNAMITE.

B. SEPTIC TANK INSTALLED IN THE PIT SHOWN ABOVE.

FIGURE 8



A. SEWAGE DISPOSAL WELL UNDER CONSTRUCTION AT BEND.



B. OPAL SPRING IN THE CROOKED RIVER CANYON.

Individual sewage disposal systems are generally operated until the system becomes plugged and sewage backs up into the system or breaks through to the surface. The chief cause of failure of a disposal well system is the lack of septic tank maintenance. The septic tank becomes filled with sludge, and the excess sludge is carried into the disposal well where it plugs the cracks and openings in the volcanic rock. Repairs are generally made by pumping out the septic tank and cleaning and deepening the disposal well with a well drilling machine. The practice of "shooting" the disposal wells with dynamite as a repair operation is falling into disuse.

2. Storm Runoff

The cities of Bend and Redmond use drilled disposal wells for street drains. These wells are generally located at the edge of the street and are covered with steel grates. These disposal wells are usually 6 or 8 inches in diameter and less than 100 feet in depth. Some penetrate large cracks or joints in the lava and can dispose of large quantities of water; others are located in relatively tight lava and are easily plugged with debris.

3. Farm Drainage

Because many people use irrigation water from the numerous canals and ditches for their domestic water, there are restrictions as to the quality of water that can be returned to

the ditches. Irrigation water also collects in some areas where surface drainage is poor. A number of farm operators in the area north of Redmond have constructed farm disposal wells for the disposal of excess irrigation water.

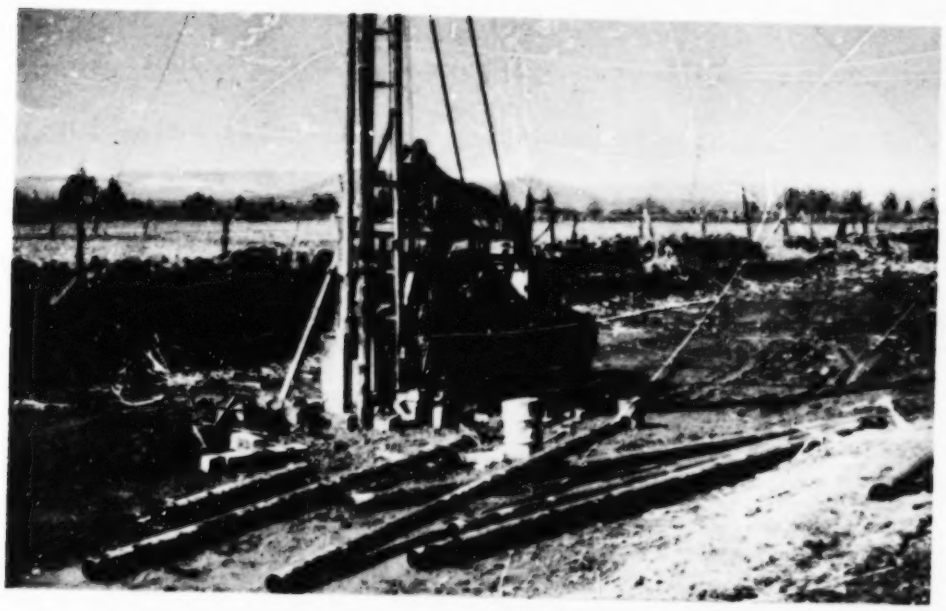
These farm disposal wells (Figure 9) are generally 6 inches in diameter and are completed with perforated casing installed at the surface. The large annular space excavated around the perforated casing is backfilled with gravel. Irrigation water is fed into the disposal wells directly from ditches, or the disposal wells may serve as the overflow for farm ponds. These disposal wells range from about 45 to over 200 feet in depth. Some can reportedly dispose of several cubic feet per second (1 cfs = 449 gallons per minute). No method of physically controlling the injection was observed at the farm disposal wells examined and all liquid waste coming to the well was injected into the ground.

As farm drainage has been one of the functions supported by the U. S. Soil Conservation Service, some of the farm drain wells in the Redmond area have been constructed with the Federal Government paying half of the cost.

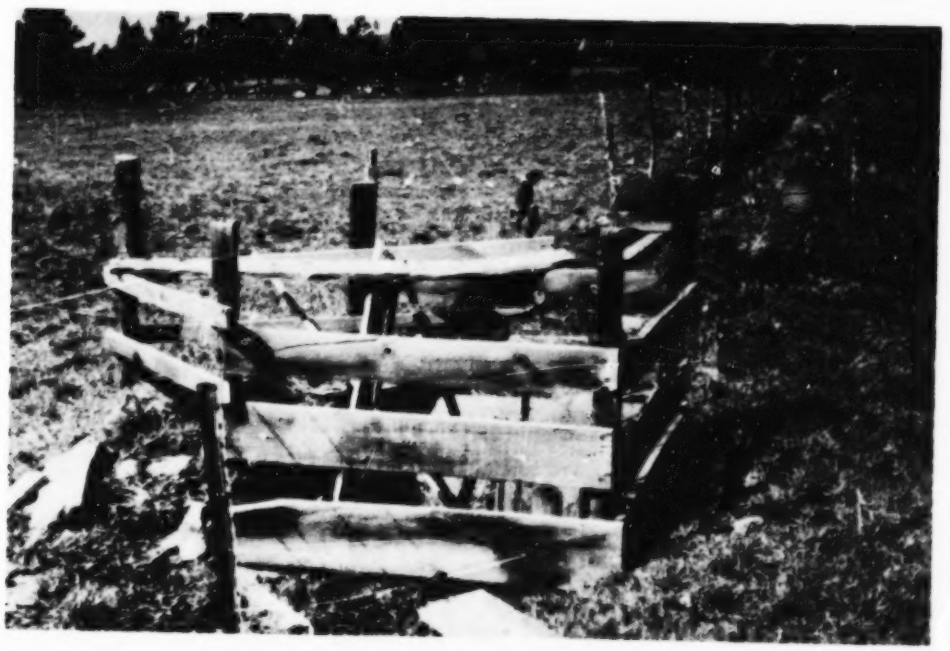
D. Well and Spring Numbering System

The well and spring numbers used in this report indicate the township, range, section, and 40-acre subdivision in which the well, spring, or drain well is located. The first number is

FIGURE 9



A. FARM DRAIN WELL UNDER CONSTRUCTION NEAR REDMOND.



B. TYPICAL FARM DRAIN WELL FOR THE DISPOSAL OF FIELD RUNOFF.

the range. All of the project area lies south and east of the Willamette Base Line and Meridian, so the letters "S" and "E" are omitted. The number following the hyphen indicates the section and the letter indicates the 40-acre subdivision of a section as depicted in the following diagram. The number following the letter is the serial number of the particular well, spring, or drain well. For example, the well numbered 14/13-28K1 indicates the well is located in the NW¼ SE¼, Section 28, Township 14 South, Range 13 East, and is the first well noted in this 40-acre tract.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

IV. BEND AREA

A. Geology and Occurrence of Ground Water

Most of the Bend Area is underlain by basaltic lava flows that originated in the Newberry Crater area south of Bend. One of the more recent flows extends north into the Crooked River Canyon and forms the intracanyon basalt (Figure 2).

The surficial lava flows in the Bend area have a total thickness of 100 to 150 feet and underlie most of the area east of the Deschutes River. These lavas contain some lava tubes or caves that formed when molten lava flowed out from beneath a cooled and hardened crust (Figure 10). They also contain numerous open joints and fractures that give them a high porosity and permeability. These lavas serve as the chief zone for the disposal of liquid wastes in both the Bend and Redmond areas.

These younger lavas generally overlie a sedimentary formation that contains some interbedded lava flows. Strata in this formation, which are believed to be part of the Madras Formation, are generally logged by well drillers as sandstone, conglomerate, cinders, sand, and gravel. The logs of 22 wells over 400 feet in depth that are listed in Table 2 of the Appendix. They indicate that below a depth of 100 feet about 80 percent of the material penetrated is sedimentary and 20 percent is lava.

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FIGURE 10

A. ENTRANCE TO HORSE CAVE, A LAVA TUBE LOCATED NEAR BEND.

B. DISPOSAL SUMP UTILIZED BY THE BEND MUNICIPAL SEWER SYSTEM FOR THE SUBSURFACE DISPOSAL OF SEWAGE.

The Bend area is also marked by a number of faults. These generally have a northwestward trend. One lies immediately east of town where it forms a prominent scarp adjacent to Pilot Butte (Figure 11). Faults can form either subsurface barriers that can impound water like a subsurface dam or they may serve as conduits that can transmit water from shallow to deeper zones. The hydrologic effects of the various fault zones in the Bend area are not known at this time.

The regional water table at Bend lies within the Madras Formation, some 500 to 600 feet below land surface at an altitude of about 3,000 feet. Contours on the regional water table (Plate 1) show that it has a gentle gradient to the north. Consequently, ground water in the Bend area flows in a generally northerly direction.

The first deep test well (18/12-5E1) was drilled by Brooks-Scanlon, Inc. in 1956. This test well, which is in the City of Bend, was drilled to a depth of 902 feet. It had a static water level of 564 feet below land surface and a yield of 1,300 gpm with 7 feet of drawdown. Since that time, several dozen deep wells have been drilled in the Bend area for domestic water supplies. These wells are shown on Plate 1 and are described in Table 1 of the Appendix.

Most of the wells located in Section 8 and 17, T.17S., R.12E., north of Bend develop ground water from a perched sand and cinder

zone in the Madras Formation. These wells generally range from 100 to 200 feet in depth while the regional water table is close to 600 feet below land surface. Most of the perched ground water in the Bend area is believed to be recharged from canal losses and irrigation, although some of the perched zones may be recharged from the Deschutes River. The deepening of a well developing perched ground water often results in the loss of the perched water supply out the bottom of the well into the underlying materials and the creation of a new source of recharge for the underlying water table.

B. Liquid Waste Disposal

It is estimated that there are more than 3,000 disposal wells in the Bend area. Most of these are located in and adjacent to the City of Bend. These disposal wells range from shallow wells less than 20 feet in depth to deep wells exceeding 200 feet in depth. The deep wells are confined chiefly to the Awbrey Butte area in the western part of Bend where there has been considerable difficulty in locating permeable zones for waste disposal.

Most of the disposal wells in Bend are located east of the Deschutes River. These wells are believed to average about 50 feet in depth and are drilled into the surficial lava flows. The disposal wells located west of the Deschutes River in Bend are believed to average slightly deeper, due to the lack of the sur-

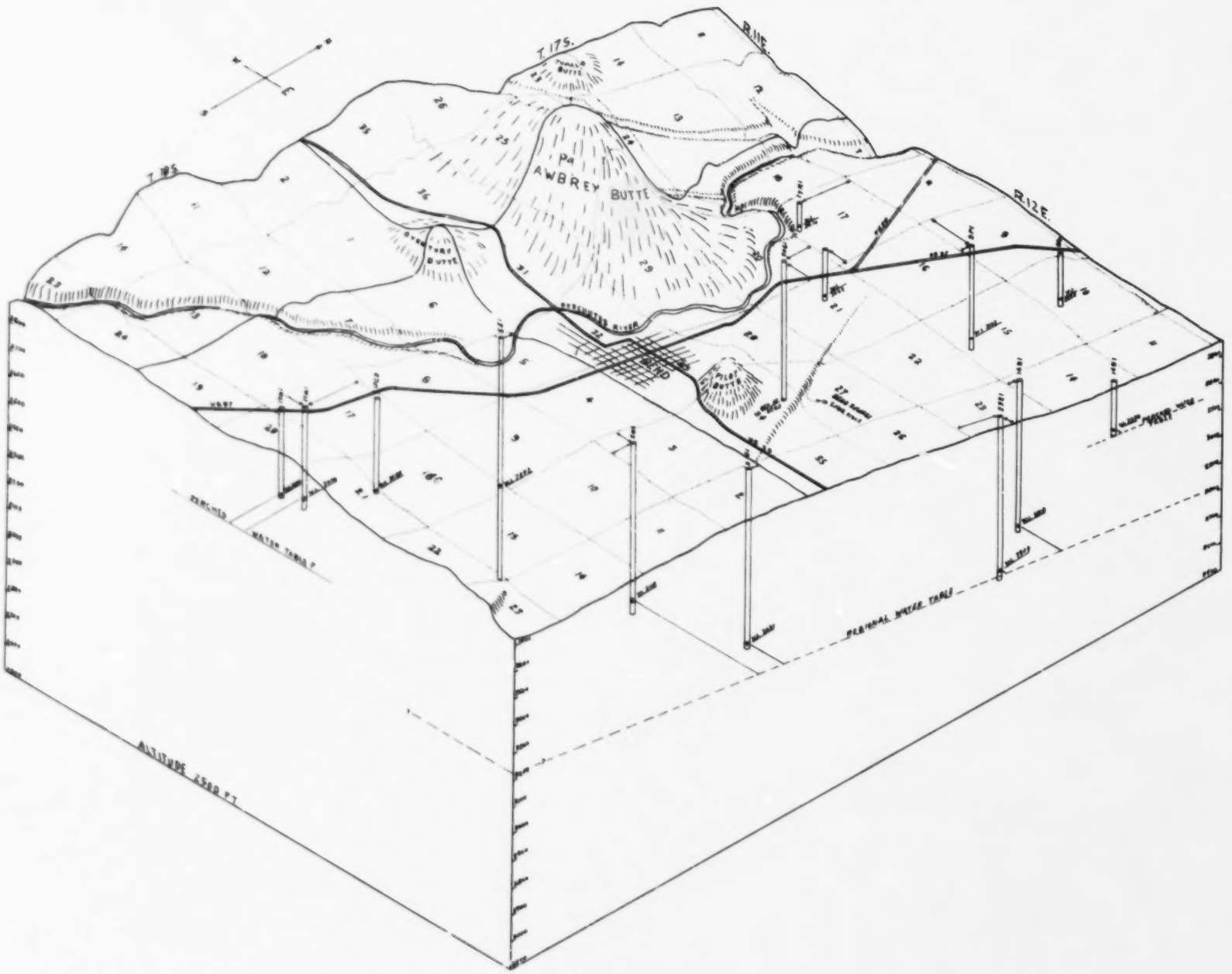

FIGURE II —BLOCK DIAGRAM OF THE BEND AREA SHOWING REPRESENTATIVE WELLS AND THE ALTITUDE OF WATER LEVELS

ficial lavas, and the necessity of drilling into the less permeable sedimentary deposits.

Very few of the disposal wells penetrate into lava tubes or other large openings in the lava. Most of the wells discharge waste into open joints or fractures in the lava. Layers of volcanic cinders are sometimes encountered in disposal wells, but these porous zones are easily plugged with solids and do not generally prove satisfactory for waste disposal.

The City of Bend operates a small sewer system that serves part of the downtown area and a small residential area in the northeast part of town. This system has a total of 343 connections and was constructed about 1912.

The raw sewage is discharged into an Imhoff tank located in SW¼, NW¼, Section 24, T.17S., R.12E. The effluent from this tank flows southeast through a pipeline and an open ditch for about 1,500 feet to a small sump that has been excavated into the top of a lava flow. Downward infiltration from this sump has been the only method of sewage disposal for the municipal system since it went into operation more than 50 years ago (Figure 10B).

The Imhoff tank receives very little maintenance and the effluent is essentially raw sewage. A composite sampler was installed in the ditch near the discharge sump and hourly samples of the effluent were collected for a 24-hour period in January 1967. During this same 24-hour period, a water stage recorder was oper-

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ated behind a rectangular weir to provide flow information. The hourly flow and the amount of suspended solids in the effluent are shown in Figure 12. A chemical analysis of the composite sample and chemical analyses of miscellaneous grab samples of the sewage effluent from this system are given in Table 15 in the Appendix.

It is possible that the discharge sump overlies a lava tube in the lava, and that the effluent discharges into such a tube. Horse Cave, which is located about 2 miles to the east, is typical of the lava tubes in the Bend area (Figure 10A). If the sump overlies a lava tube, the effluent would cascade into the tube through cracks and joints. The effluent would then flow as a stream down the floor of the tube and collect in depressions. Losses from the tube would be by downward infiltration into the underlying lavas. As most of the lava tubes in the Bend area are relatively short, it is doubtful that any subsurface stream of sewage in a lava tube would extend more than a mile from the disposal sump. Well logs indicate that the surficial lava is relatively thin and any lava tube in this area would probably occur within the first 100 feet below land surface.

The City of Bend has contracted with a consulting engineering firm to make a study of the sewage collection and disposal problem in the Bend area. It would appear from the available information that the existing area of subsurface disposal utilized by the

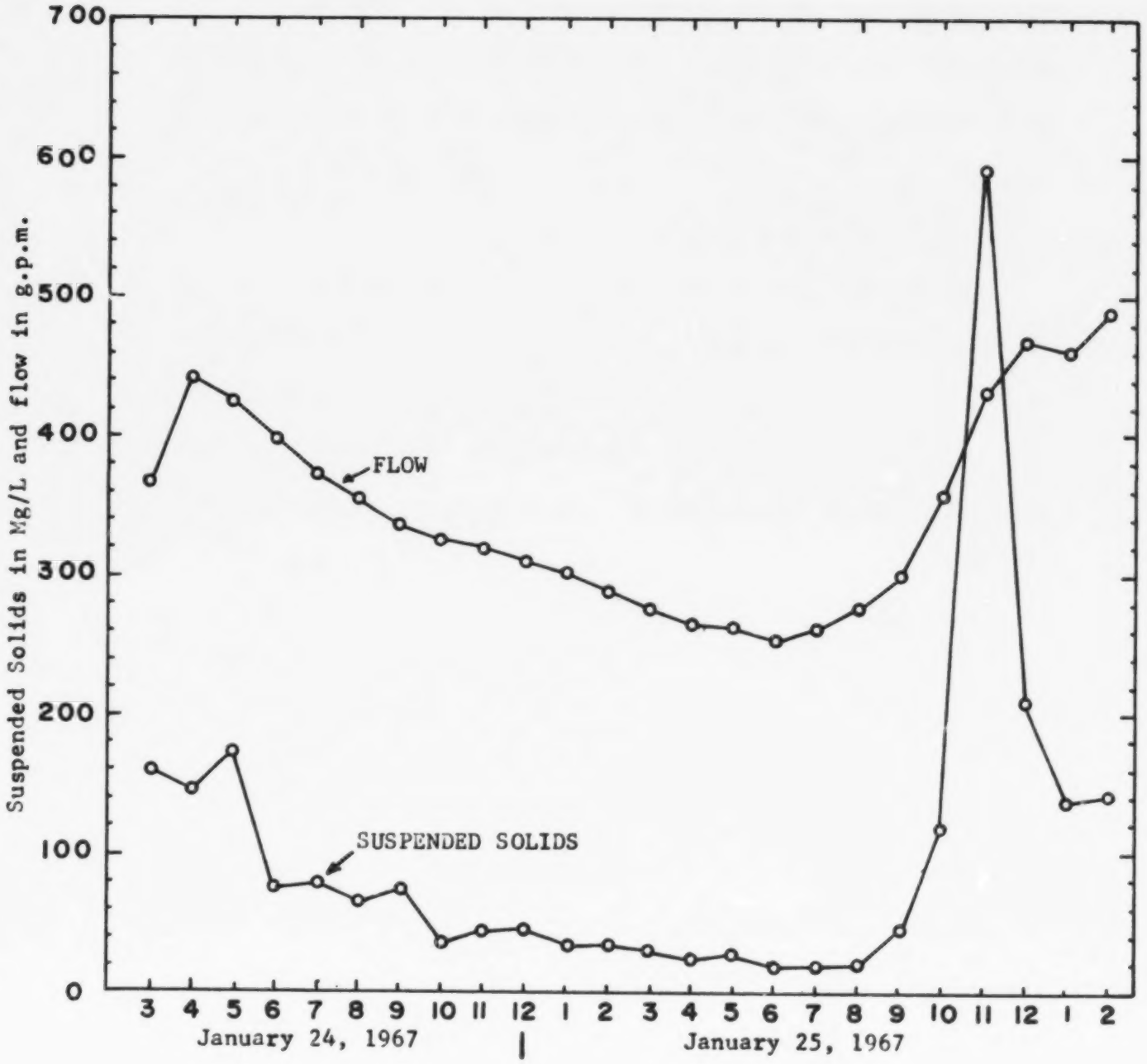

FIGURE 12. --HOURLY FLOW AND SUSPENDED SOLIDS OF THE EFFLUENT FROM BEND'S MUNICIPAL SEWER SYSTEM

City could serve as the disposal site for the disposal of adequately treated sewage. Some geophysical exploration and test drilling would verify the existence of a lava tube in this area.

C. Chemical Quality of Ground Water

Most of the ground water developed in the Bend area is low in dissolved mineral matter. It is slightly alkaline with a pH of about 8. Chemical analyses of water from 28 wells in the Bend area are given in Table 3 of the Appendix. The range and average concentration of the various determinations are as follows:

	Range	Average
Calcium	4.5-31 mg/1	14 mg/1
Magnesium	1.0-26 mg/1	12 mg/1
Sodium	2.8-27 mg/1	12 mg/1
Alkalinity	32.0-178 mg/1	75 mg/1
Sulfate	0.0-25 mg/1	4 mg/1
Chloride	0.0-15 mg/1	2 mg/1
Phosphate	0.0-0.74 mg/1	.34 mg/1
Dissolved Solids	65.0-223 mg/1	125 mg/1
Hardness	26.0-130 mg/1	59 mg/1
Conductivity	66.0-343 μMHOS	163 μMHOS

The test for methylene blue active substance (MBAS) indicates the presence of detergents, a common constituent of most sewage. The precision of this particular test is about .003 mg/1, and any determination of .003 mg/1 or less is questionable. About half of the water wells tested in the Bend area had MBAS concentrations greater than .003 mg/1.

V. REDMOND AREA

A. Geology and Occurrence of Ground Water

The geology of the Redmond area is similar to that of the Bend area. The surficial lava is somewhat thinner, generally averaging less than 100 feet. The lava contains numerous cracks and joints and serves as the chief rock unit for liquid waste disposal.

The lava overlies the Madras Formation, which is generally recorded as sandstone and conglomerate in the water-wells logs. The logs of many wells in the Redmond area are given in Table 6 of the Appendix, and their locations are shown on Plate 2. The logs of wells 15/13-4H1, -18H1, and -31J1 show that the Madras Formation extends to depths exceeding 400 feet.

The John Day Formation crops out in the Smith Rock area northeast of Redmond. This formation is mostly a light colored tuff that has a low permeability and generally serves as a barrier to ground-water movement. The John Day Formation is believed to underlie most of the Redmond area, where its upper surface serves as the base of the water-bearing formations. Little ground-water movement would occur in the John Day Formation or in older underlying formations.

A major period of deformation and erosion followed the deposition of the John Day Formation. (The Columbia River Basalt

Formation was also involved in this deformation but information as to the occurrence of the Columbia River Basalt Formation in the Middle Deschutes Basin is meager). The major valleys eroded in these older rocks were completely buried by the deposition of the Madras Formation. The exact locations of these ancestral valleys in the Redmond area are not exactly known. Their existence, however, is believed to play a major role in controlling the occurrence and movement of ground water.

The intracanyon lava, the source of which was in the Newberry Crater area south of Bend, flowed north and covers a broad area lying east of Bend and Redmond. This lava flowed into the ancestral Crooked River Canyon near O'Neil and partially filled the canyon for at least 30 miles downstream. The intracanyon lava exceeded 400 feet in depth in parts of the Canyon.

The present Crooked River Canyon was eroded into the intracanyon lavas and into the Madras Formation. The location of the present canyon does not exactly coincide with the ancestral one, and the canyon walls may be composed of either Madras Formation or intracanyon lava. Many remnants of the intracanyon lava remain as broad terraces within the present canyon (Figure 2A).

One striking feature in the Crooked River Canyon is the contact between the intracanyon lava and the Madras Formation. This contact, which represents the wall of the ancestral canyon, shows that the ancestral canyon had almost a perfect V-shape.

This is in striking contrast to the differential erosion in the present canyon (Figure 2), and may be attributed to different climatic conditions during the two erosion periods.

When the Redmond area was settled, deep well drilling equipment was not readily available, and pumping equipment to withdraw ground water from great depths was costly. Many early settlers carried their water for stock and domestic uses. With the construction of irrigation canals, the "ditch" water became the chief source of domestic and stock water. Until a few years ago, there were very few water wells in the Redmond area. This situation has rapidly changed; problems of maintaining water quality in the irrigation canals has resulted in the construction of numerous wells for domestic supplies.

Most of the wells in the area lying north and west of Redmond are 200 to 300 feet deep, and most of these develop water from a sand layer in the Madras Formation. The water table is at an altitude slightly above 2700 feet in the vicinity of Redmond, which at most places is 200 to 300 feet below land surface (Figure 13).

Recharge to this water-bearing zone is believed to come chiefly from canal losses and farm irrigation. The water table in the vicinity of Redmond has a very gentle slope to the northwest. The ground water discharges to both the Deschutes and Crooked Rivers (Plate 2).

B. Liquid Waste Disposal

The City of Redmond has no municipal sewer system and practically every residence or business establishment has its own septic tank and disposal well. There is a small area in the southwestern part of the City that has several feet of soil overlying the lava where some conventional drain fields have been constructed and operated successfully.

It is estimated that there are more than 1,000 disposal wells in Redmond. These range from a few feet to over 100 feet in depth and are believed to average about 60 feet. Open cracks and joints in the lavas encountered in these wells serve as the principal openings for waste disposal.

Practically all of the waste in the Redmond area is domestic sewage as there are no large industrial waste disposal systems utilizing disposal wells. The use of wells for disposing of plywood glue waste was attempted at one time but this method did not prove feasible.

C. Chemical Quality of Ground Water

Ground water in the Redmond area is slightly alkaline with a pH of about 8. Chemical analyses of water from 45 wells are given in Table 7 of the Appendix. These analyses show that the ground water developed in the Redmond area contains about twice the amount of dissolved minerals as the ground water sampled

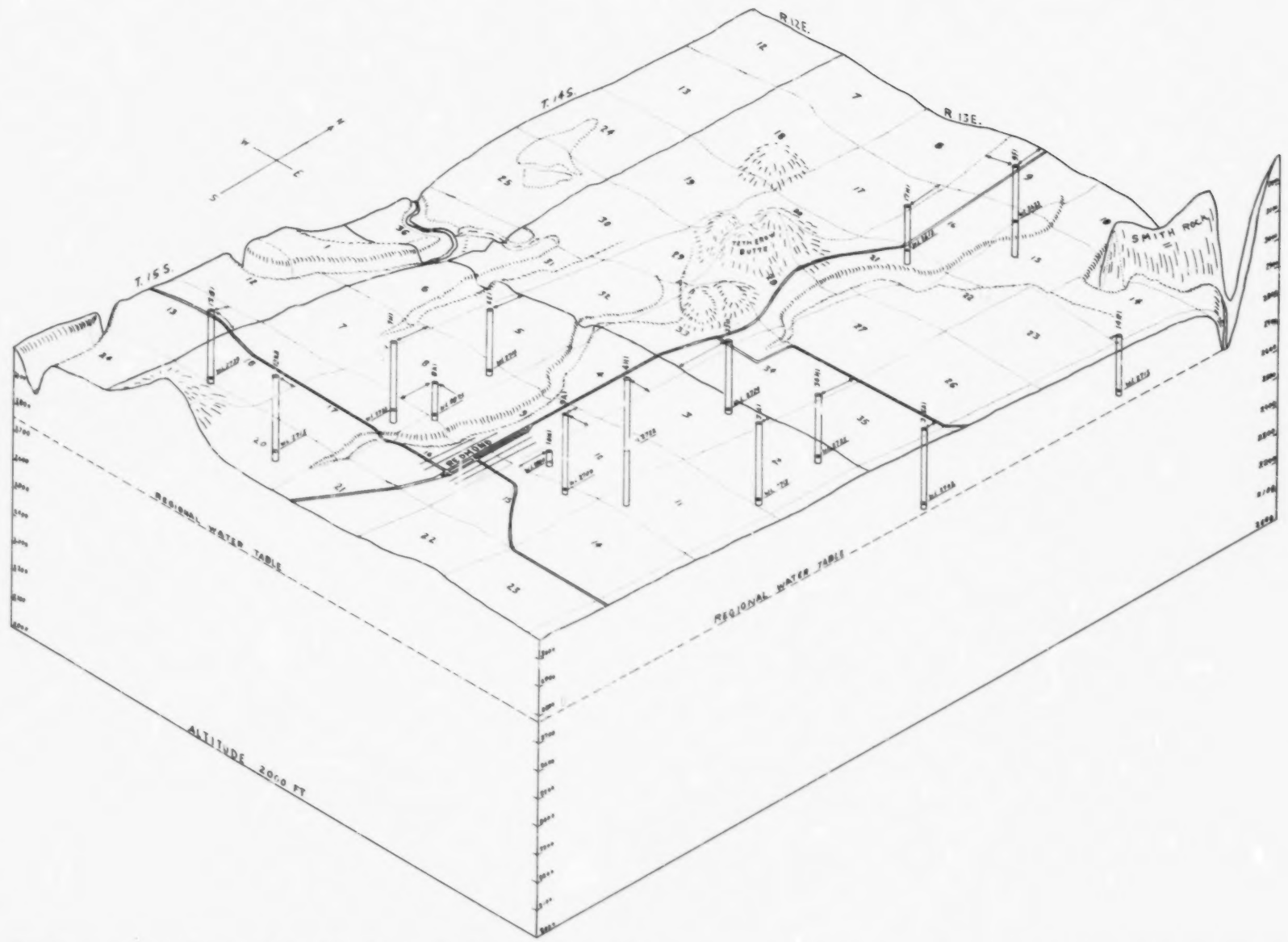

FIGURE 13—BLOCK DIAGRAM OF THE REDMOND AREA SHOWING REPRESENTATIVE WELLS AND THE ALTITUDE OF WATER LEVELS

in the Bend area. The range and average concentration for the chemical determinations are as follows:

	Range	Average
Calcium	13-82 mg/1	36 mg/1
Magnesium	4.8-99 mg/1	33 mg/1
Sodium	8.3-49 mg/1	24 mg/1
Alkalinity	56-390 mg/1	182 mg/1
Sulfate	1.0-25 mg/1	9 mg/1
Chloride	0.0-15 mg/1	4 mg/1
Phosphate	.12-.62 mg/1	.31 mg/1
Dissolved Solids	93-437 mg/1	245 mg/1
Hardness	60-349 mg/1	153 mg/1
Conductivity	167-681 MHOS	391 MHOS

Forty-four water wells were also tested for methylene blue active substance (MBAS) which is an indicator for detergents, and 31 had concentrations that exceeded .003 mg/1.

D. Springs in the Crooked and Deschutes River Canyons

The crooked River Canyon from Smith Rock State Park in Section 11, T.14S., R.13E. (Plate 2) to Lake Chinook behind Round Butte Dam is almost one continuous spring area. The springs discharge from cracks and joints in the intracanyon lavas and from permeable layers in the Madras Formation. Many of the springs occur in the bed of the Crooked River or in the bordering talus slopes and are not visible from the surface.

The largest spring in the Crooked River Canyon is Opal Spring (Figure 8B) with a flow in excess of 100 cfs (12/12-33G1). This spring is near river level on the east bank of the Crooked River in Section 33, T.12S., R.12E. and issues from a permeable

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zone in the Madras Formation. The Deschutes Valley Water District uses water from Opal Spring as a source of domestic water. The spring water is pumped to a reservoir near the rim of the canyon, some 900 feet above the spring, and is distributed throughout the Madras area by gravity flow.

An upper spring at Opal Spring issues from a lava interbed in the Madras Formation some 100 feet above the main spring (12/12 -33G2). Chemical analyses of water from these two springs given in Table 14 of the Appendix show that the water from the upper spring is appreciably higher in dissolved minerals and indicate that the springs do not have a common source. The ground water supplying the main spring at Opal Spring is believed to be moving northward from the Bend area in an interbed of lava lying near the base of Madras Formation. Such an interbed, which was named the Pelton Basalt by Stearns (9), crops out further downstream.

One of the most interesting springs in the Crooked River Canyon occurs on the west wall of the canyon a few miles upstream at the George Bell Ranch (13/12 -14F1). This spring, which has been described by Stearns in his report on the Middle Deschutes River Basin, issues from a contact zone in a lava interbed in the Madras Formation. This interbed is composed of several lava flows and forms a vertical cliff that extends along both sides of the canyon. The spring discharges from a zone

lying about midway down the vertical cliff and about 100 feet above river level. At one time the available head was utilized to develop power and operate rams, but the water now being used from these springs is pumped by means of a turbine pump that is hung down the face of the cliff. The unusual occurrence of this spring, some 100 feet above river level, was pointed out by Stearns. The Crooked River Canyor at this point does not exactly coincide with the ancestral canyon that was partially filled with the intracanyon lavas, and the center of the ancestral canyon lies slightly to the west of the present canyon. As both the ancestral canyon and the present canyon extend to approximately the same depth, the contact zone feeding this spring must be cut by the contact with the intracanyon lavas a short distance back from the outcrop area. It is probable that the ground water supplying this spring is moving northward through the intracanyon lavas and is impounded in the ancestral canyon by a change in permeability in the lavas. The impounded ground water spills over into the present canyon via the permeable contact zone in the lava interbed.

Visible springs are not common in the Deschutes River Canyon, however, a large spring that issues from an intracanyon lava flow along the east bank of the Deschutes River in the SW¼ SW¼ Section 34, T.13S., R.12E. was observed and sampled. The water issues in a line of springs some 20 feet above the river. Another spring

was observed, but not visited along the west bank of the Deschutes River in the NE¼ SW¼ Section 5, T.13S., R.12E.

The springs in the Crooked River Canyon vary appreciably in chemical quality. The chemical analyses of water from a few of these are given in Table 14 of the Appendix. As the gradient of the Crooked River is somewhat steeper than the northward dip of the strata in the Madras Formation, ground water issues from older or deeper strata progressively downstream. The ground water lowest in dissolved mineral matter moves through permeable strata near the base of the formation and discharges to the river in and near Opal Spring. This water is very similar in quality to some of the ground water developed in Bend area, being very soft and having total dissolved solids in the order of 100 mg/1.

Further upstream the water from springs located in Section 32, T.13S., R.13E. is hard and total dissolved solids average about 240 mg/1. This water is very similar to ground water in the Redmond area. This difference in water quality indicates that the ground water within the Madras Formation is stratified by confining layers and that the water improves in quality with depth in the formation. Water similar in quality to that of Opal Springs probably occurs near the base of the Madras Formation in parts of the Redmond area.

The difference in water quality in the springs in the Crooked River Canyon indicates that the water has a different history.

One aid in interpreting the history of the water is its age since falling as precipitation. One method of dating water is by its tritium content.

Tritium is a radioactive isotope of hydrogen that is produced by cosmic rays in the atmosphere. It has a half life of about 12.5 years. The natural tritium content of rainwater prior to the introduction of large amounts of tritium to the atmosphere from thermonuclear explosions was in the order of 5 Tritium Units. A Tritium Unit (T.U.) has been defined as follows:

$$1 \text{ T.U.} = \frac{\text{Tritium Atoms}}{\text{Hydrogen Atoms}} \times 10^{18}$$

A Tritium Unit is equivalent to about 0.008 tritium disintegrations per minute per milliliter of water. With electrolytic enrichment and gas counting, the minimum detectable activity is 0.3 T.U. or a maximum age of about 50 years. Since there has been so much tritium contamination since 1954 a tritium assay of water at this time can generally tell whether the water is post 1954 in age, older than 1917, or somewhere in between.

Five samples of spring water were collected on May 22, 1967, from springs in the Crooked and Deschutes River Canyons for tritium assays. The assays were made by Isotopes, Inc., Westwood, New Jersey. The sampling points and the assay results are as follows:

SOURCE OF SAMPLE	TRITIUM ASSAY
Zilko's Spring located in the Crooked River Canyon in the SE¼ SE¼, Section 32, T.13S., R.13E.	19.5 ± .8 TU
George Bell Spring located in the Crooked River Canyon in the SE¼ NW¼, Section 14, T.13S., R.12E.	4.5 ± .4
Upper Spring at Opal Spring located in the Crooked River Canyon in the SW¼ NE¼, Section 33, T.12S., R.12E.	16.8 ± .8
Lower Spring at Opal Spring located in the SW¼ NE¼, Section 33, T.12S., R.12E.	1.4 ± .3
Unnamed spring in the Deschutes River Canyon in the SW¼ SW¼, Section 34, T.13S., R.12E.	4.2 ± .3

These assays indicate that the water from the Lower Spring at Opal Spring entered the ground prior to any contamination from thermonuclear testing and is in the order of 23 years in age (1944).

If the water from Opal Spring is recharged from the Deschutes River just downstream from Benham Falls, the ground water velocity has averaged about 9,000 feet per year or about 25 feet per day. If the recharge occurs further upstream, the velocity would be proportionally faster.

The water samples from the other four springs show the effect of tritium contamination from thermonuclear testing and are appreciably younger than the sample from Opal Springs. In general, the ground water moving through the strata lying near the base of the Madras Formation is older than ground water moving through overlying strata. This is believed due to the large amount of recharge to the shallower strata from irrigation, canal losses, and disposal wells. Annual sampling of water from Opal Spring for tritium assays would provide an arrival time of the first wave of tritium contaminated water and would give a more accurate measure of the ground water travel time for the spring.

VI. MADRAS AREA

A. Geology and Occurrence of Ground Water

The City of Madras is located in a valley that is separated from the Deschutes River by a broad lava-capped plateau named Agency Plain. Drainage from Madras flows to the Deschutes River through the deep narrow canyon of Willow Creek, which cuts through Agency Plain (Plate 3). The city is underlain by the Madras Formation. The low permeability of some of the sedimentary strata in this formation has resulted in the widespread use of drilled wells for waste disposal.

The rural area around Madras obtains most of its domestic water from Opal Spring through the Deschutes Valley Water District System. The widespread availability of this excellent water has resulted in the construction of very few water wells in the area. The City of Madras obtains its municipal water from the North Unit Irrigation District canal during the irrigation season. This water is diverted from the Deschutes River at Bend. During the non-irrigation season, the municipal system is supplied by two deep wells located at the north edge of town. The No. 1 well (11/13 - 1D1) was drilled about 1910 and has been in use since that time. It is 415 feet deep and develops water from a gravel stratum in the Madras Formation. Well No. 2, which was drilled in 1966, is 451 feet deep and also develops water from a gravel stratum in the Madras Formation. The static water level in this

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well was 326 feet below land surface in 1966. The logs of these two wells are given in Table 10 of the Appendix.

The water table at Madras is at an altitude of about 1900 feet (Figure 14). It is believed to have a gradient to the northwest beneath Agency Plain towards the Deschutes River and Lake Simtustus, the reservoir behind Pelton Dam. The depth to the water table exceeds 500 feet beneath Agency Plain.

A perched ground-water body occurs at shallow depth beneath most of the City of Madras. The water occurs in gravel and sandstone and is perched by an impermeable layer of sandstone in the Madras Formation. At places, the perched ground water occurs at depths less than 20 feet below land surface. The water is used for lawn irrigation and other non-domestic uses.

B. Liquid Waste Disposal

It is estimated that there are in the order of 500 disposal wells in the Madras area. Some near surface layers of tuff and sandstone have restricted the operation of drainfields and have made the use of drilled wells the local method of waste disposal.

The disposal wells at Madras are generally deeper than those at Bend and Redmond and are believed to average over 100 feet. Some of the disposal wells on Agency Plain extend to depths of 300 feet or more in order to encounter a permeable stratum.

A permeable unsaturated lava interbed in the Madras Formation is generally encountered between 80 to 150 feet below land surface

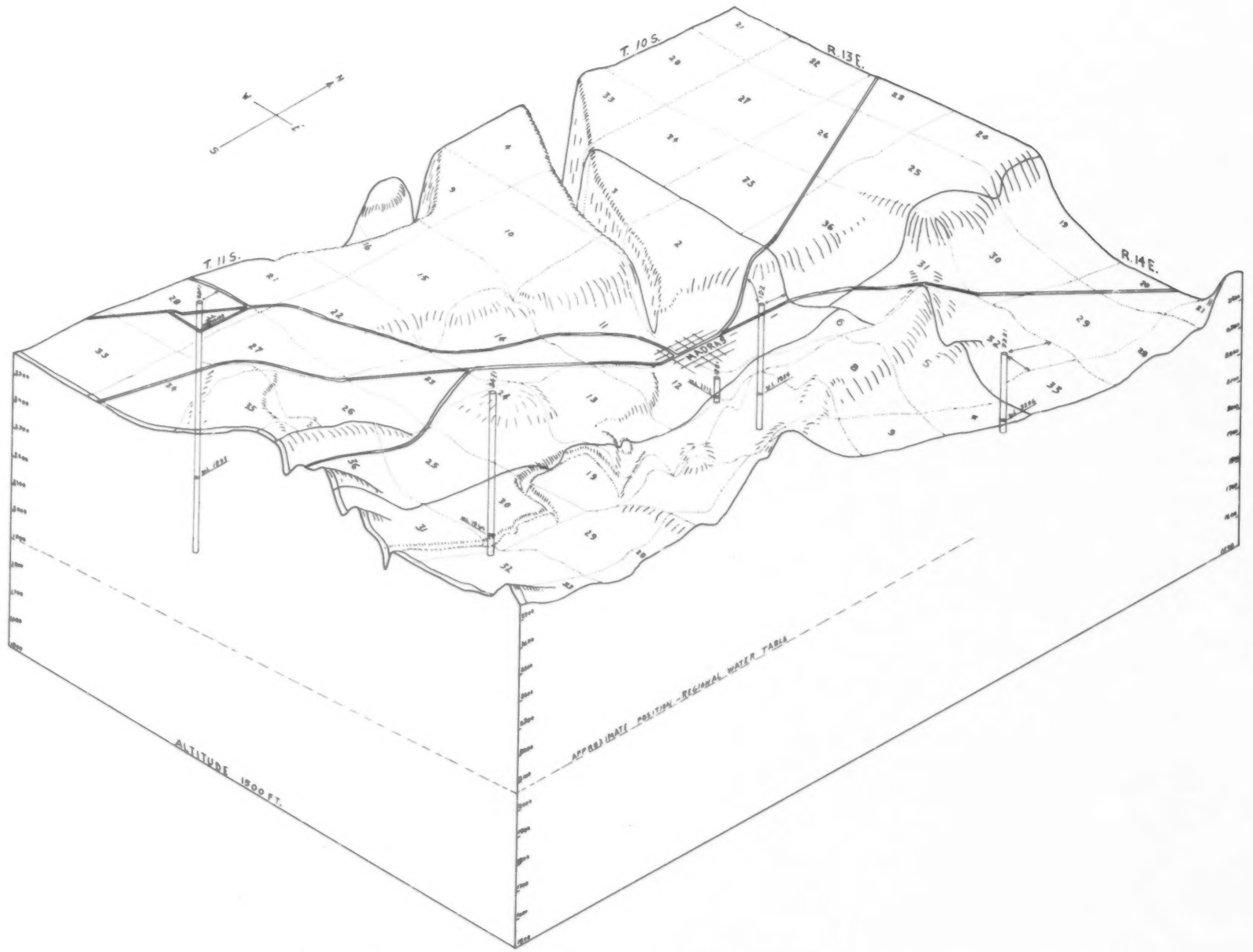

FIGURE 14—BLOCK DIAGRAM OF THE MADRAS AREA SHOWING REPRESENTATIVE WELLS AND THE ALTITUDE OF WATER LEVELS

within the City of Madras. This interbed serves as the chief zone for waste disposal. The perched ground-water zone, which occurs beneath most of the City, overlies this lava interbed. The disposal wells are generally cased through the perched zone to keep them from caving and to reduce the recharge into the perched zone.

The lava interbed used for waste disposal at Madras contains a sizable reservoir of air. Changes in atmospheric pressure cause pressure differences to develop between the atmosphere and the confined air reservoir. Such pressure differences cause many of the disposal wells to blow or suck air, depending upon whether a high or low atmospheric air mass is moving into the area. As many of the disposal wells are not vented at the well, the blowing or sucking of air generally occurs at the plumbing vent on the roof of each house. It was reported that one can hear the roar or whistle of air moving in or out of these vents throughout the City on some still nights.

The disposal wells at the town of Metolius southwest of Madras, are believed to average about 60 feet in depth. The waste is discharged into the surface lava that underlies most of Agency Plain.

C. Chemical Quality of Ground Water

Water from the deep city wells at Madras contain about the same amount of dissolved minerals as ground water in the Redmond

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area. It is higher in sulfate and chloride, but is lower in phosphate. The following is a chemical analysis of water from City Well No. 1 (11/13-1D1):

Silica	54	mg/1
Calcium	41	mg/1
Magnesium	27	mg/1
Sodium	31	mg/1
Alkalinity	141	mg/1
Sulfate	27	mg/1
Chloride	14	mg/1
Phosphate	.03	mg/1
Dissolved Solids	276	mg/1
Hardness	157	mg/1
Conductivity	399	MHOS

Samples of some of the perched ground water at Madras show that it is much higher in dissolved mineral matter than the deeper ground water. The total dissolved solids from three shallow wells at Madras averaged more than 600 mg/1. This is believed to be caused by the recharge of irrigation water and disposal well waste. The MBAS in the perched ground water samples tested was very low.

VII. DISCUSSION

A. Pollution Threat Caused by the Operation of Disposal Wells

Water discharged into the ground percolates downward through the openings occurring between the soil and rock particles. This water replaces soil moisture deficiencies and the excess continues to percolate downward due to the pull of gravity. It continues downward until it encounters a zone in which all of the voids or openings in the rock material are filled with water. This zone, which is called a "zone of saturation," may begin at the regional water table or may be a zone perched above the regional water table by a stratum of low permeability. At places water may pass through several perched zones on its route to the regional water table.

Water in a zone of saturation is under hydrostatic pressure. Differences in pressure from place to place create the hydraulic gradient or slope that provides the energy for the movement of water. Unless the water collects within a zone of saturation, there is little lateral movement.

Once the waste water or effluent from a septic tank reaches a perched or regional water table, it flows down the hydraulic gradient. As most ground-water flow is under laminar conditions, there is much less dispersion of the effluent in ground water than in surface water. The problem of tracing a particular waste from a particular source without constructing numerous observation wells is very difficult.

In the ground disposal of waste, all water that is not evaporated, transpired back into the atmosphere from the soil zone, or consumed in replacing soil moisture deficiencies will recharge some underlying ground-water zone. In a conventional drainfield disposal system, a part of the effluent generally passes into the atmosphere by evapotranspiration from within the soil zone, while in a disposal well system there may be little or no fluid loss to the atmosphere. In a conventional drainfield there is a certain amount of biological treatment and chemical sorption that takes place in the soil zone that is bypassed in a disposal well system. Any further biological treatment and chemical sorption that may occur between the soil zone and the underlying ground-water zone is further reduced by the use of a disposal well.

The chief difference between a conventional drain-field disposal system and a disposal well system is in the quantity of effluent and the degree of natural treatment the waste receives before it recharges an underlying ground-water zone. Any system that increases the quantity of subsurface waste and reduces the degree of natural treatment increases the threat of ground-water pollution. In order to reduce the threat of ground-water pollution from ground disposal of sewage to the minimum, the waste should be spread or injected as close to the surface as possible. Where the soil or rock conditions would make near surface disposal

systems inoperative, restrictions on the construction and operation of ground disposal systems would be desirable.

Well records show that numerous perched ground-water zones have developed in the Middle Deschutes Basin. These are generally recharged from irrigation and canal losses, although some recharge comes from waste disposal systems. In some parts of the area, the perched ground water is being developed and used in domestic water systems. With more and more ground disposal systems going into operation each year, the number of perched zones will increase and spread over larger areas.

One of the most serious threats to the quality of the regional ground-water supply will develop where deep uncased water wells extend to the regional water table. Of the 124 wells over 200 feet in depth listed in Tables 1, 5, and 9, 30 have casings extending to 20 feet or less from land surface. As the perched water zones develop and spread, they will intersect the existing water wells. Where these wells are uncased, the perched ground water will cascade down the well and recharge the regional ground-water supply. Figure 15 depicts how such mixing can take place. As long as there is subsurface disposal of sewage and other liquid waste, there will always be a threat to ground-water quality.

Some liquid waste receives little alteration in the ground and could cause very serious water quality problems. Such wastes as brines, petroleum products, some fertilizers, and some other

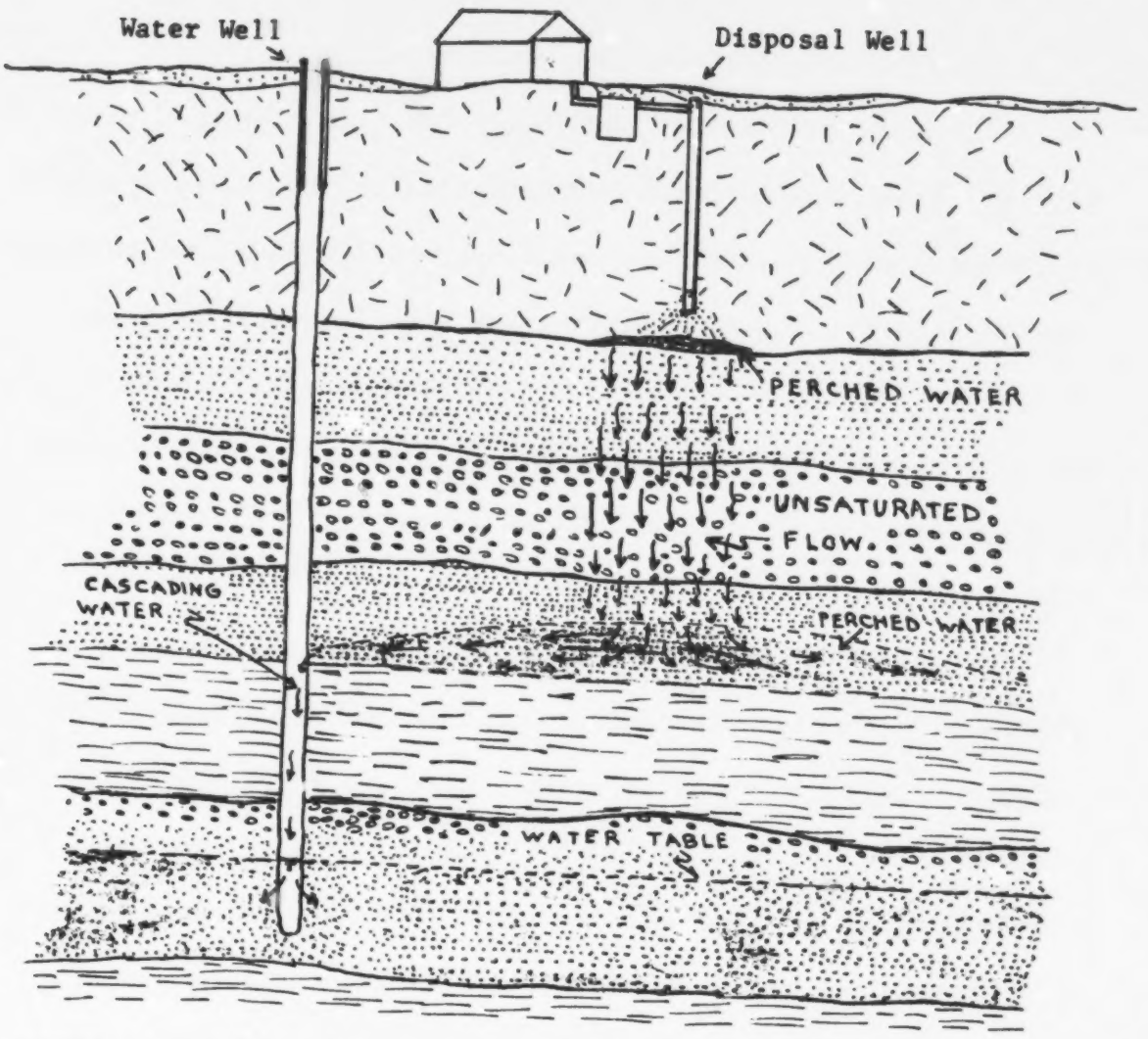

FIGURE 15. --DIAGRAM SHOWING HOW AN UNCASED WATER WELL CAN SERVE AS A CONDUIT FOR THE MOVEMENT OF PERCHED WATER TO THE REGIONAL WATER TABLE

chemical wastes should never be discharged into the ground where ground water is being developed for domestic use. Once the underlying ground-water reservoir becomes polluted with these wastes, the abatement of the source of pollution will not remove pollution in the water supply, and the supply may remain unusable for many, many years.

In some operating ground disposal systems, the effluent is chlorinated prior to discharge to the ground. This practice would tend to restrict further biological action in the ground and may result in a poorer quality water recharging the underlying water zones.

In light of the waste disposal methods used in the Middle Deschutes Basin, the question arises as to why the ground-water resources of the area are not already grossly polluted. The answer to the question involves many factors including the following:

1. The volume of liquid waste is very small when compared to the volume of ground-water recharge coming from canal and irrigation losses, and even smaller when compared to the total quantity of ground water moving through the area.

2. Most of the waste is domestic sewage which does not result in a marked chemical effect on water quality when compared to some industrial and chemical wastes.

3. The water wells used to sample water quality are not generally located at sites where sampling would be desirable, and the available water quality information may give a misleading picture of the overall ground-water conditions. For example, the closest well located down gradient from Bend's sewage disposal sump is about 4 miles away.

4. The sedimentary layers underlying the surficial lavas serve as effective filters for the removal of all suspended solids, and the great depth to the water table aids in the sorption of some chemicals.

B. Methods of Reducing the Threat of Ground Water Pollution

1. Casing of Deep Water Wells

As mentioned in the last section, deep, uncased water wells can provide direct conduits where perched ground water can gain direct access to the water table. With the construction of more and more deep water wells in the area and the disposal of more and more waste to the ground, the threat of ground-water pollution caused by uncased water wells will become serious.

One method of reducing this threat is the casing and pressure grouting of deep water wells. In order to case a well drilled in lava or consolidated rock, the well bore must be drilled with a greater diameter than the outside diameter of the casing. An 8-inch bit would generally be required to drill a 6-inch cased well. This oversize well bore results in an annular

space around the casing that can also serve as a conduit for the movement of water. In order to eliminate this added threat, the annular space should be sealed with cement grout. The very high porosity of the surficial lavas may be too great to obtain an effective grout seal near the surface, but an effective seal can be obtained in the underlying sedimentary rocks. Such construction methods would materially increase the cost of water wells, but they would provide good insurance in protecting the quality of the water supply.

The Oregon State Engineer (4) has issued "General Standards for the Construction and Maintenance of Water Wells." These existing standards, which prescribe the materials to be used and methods of constructing water wells, are not adequate to cope with the special situation common to the Bend, Redmond, and Madras areas. It is therefore recommended that special standards be adopted for this area so as to eliminate the threat of ground-water pollution caused by the construction of deep uncased water wells.

2. Elimination of Disposal Well Construction

Another method of reducing the threat of ground-water pollution would be the elimination of further disposal well construction. This could be accomplished by state statutes or local ordinances. In some areas of the state, individual sewage disposal systems must be approved by the local health department.

This is generally accomplished through a system of permits and inspections. Such a system could be utilized in enforcing a regulation banning the use of new disposal wells.

There are some parts of the Madras area and parts of the Awbrey Butte area at Bend where the low permeability of the soil would make conventional drainfield disposal systems inoperative. Further development of such areas of low soil permeability should await the availability of municipal sewers.

Another effective method of reducing disposal well construction could come from regulations of the State and Federal home finance agencies. If the availability of funds for financing new homes were dependent upon an approved sewage disposal system, other methods of sewage disposal would soon be adopted.

3. Abatement of Existing Disposal Wells

The abatement of existing sewage disposal wells presents a much more complex problem than the casing of deep water wells or the prevention of new disposal well construction. At many homes, sufficient land area for drain-field disposal systems is not available. In the business districts, the disposal wells are generally located in the alleys, and adequate space for drain-fields is not available.

As most of the existing disposal wells in the Deschutes Basin are located in the cities of Bend, Redmond, and Madras, the construction of municipal sewers and treatment plants in these

three cities would eliminate the need for most of the disposal wells in the area. When such systems are constructed, a program for the systematic plugging of all abandoned disposal wells should also be initiated.

In order to achieve better disposal practices, Federal, State, and local government agencies should take the lead in eliminating their use of disposal wells wherever possible. An inventory of Federally-owned or operated disposal wells in the project area showed the following:

Agency	Number of Disposal Wells Owned or Used
U. S. Forest Service	20
U. S. Bureau of Land Management	1
Bonneville Power Administration	4
U. S. Post Office, Redmond	1
Soil Conservation Service	1
Farmers Home Administration	1

At some of these sites, conventional tile drain fields could replace the disposal wells so as to provide a better example of waste disposal practices.

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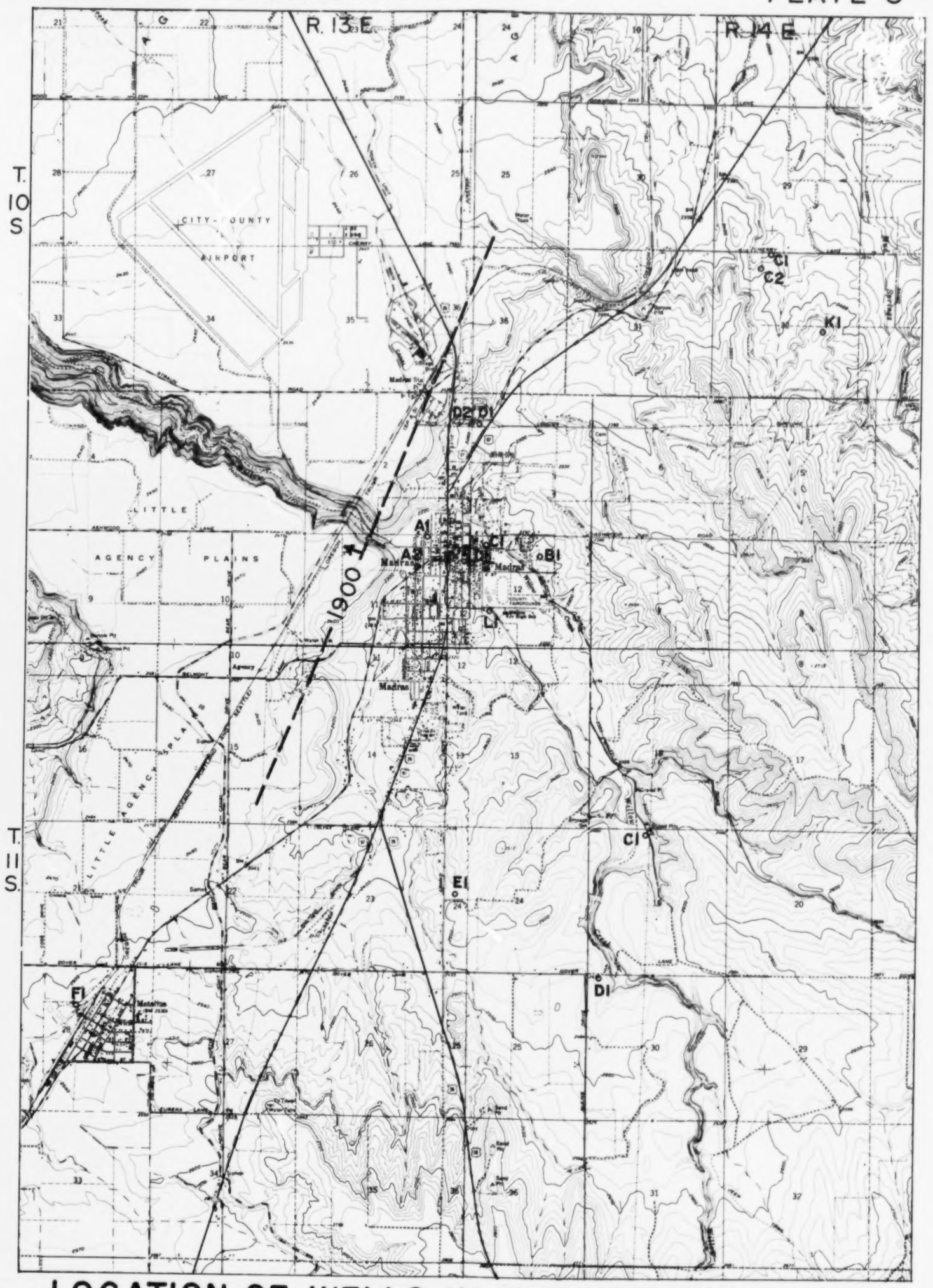
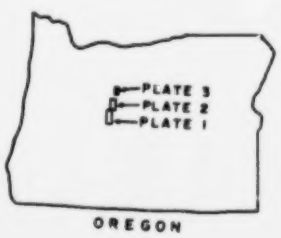
FEDERAL WATER POLLUTION
CONTROL ADMINISTRATION

PLATE 3



LOCATION OF WELLS IN THE MADRAS AREA



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EXPLANATION

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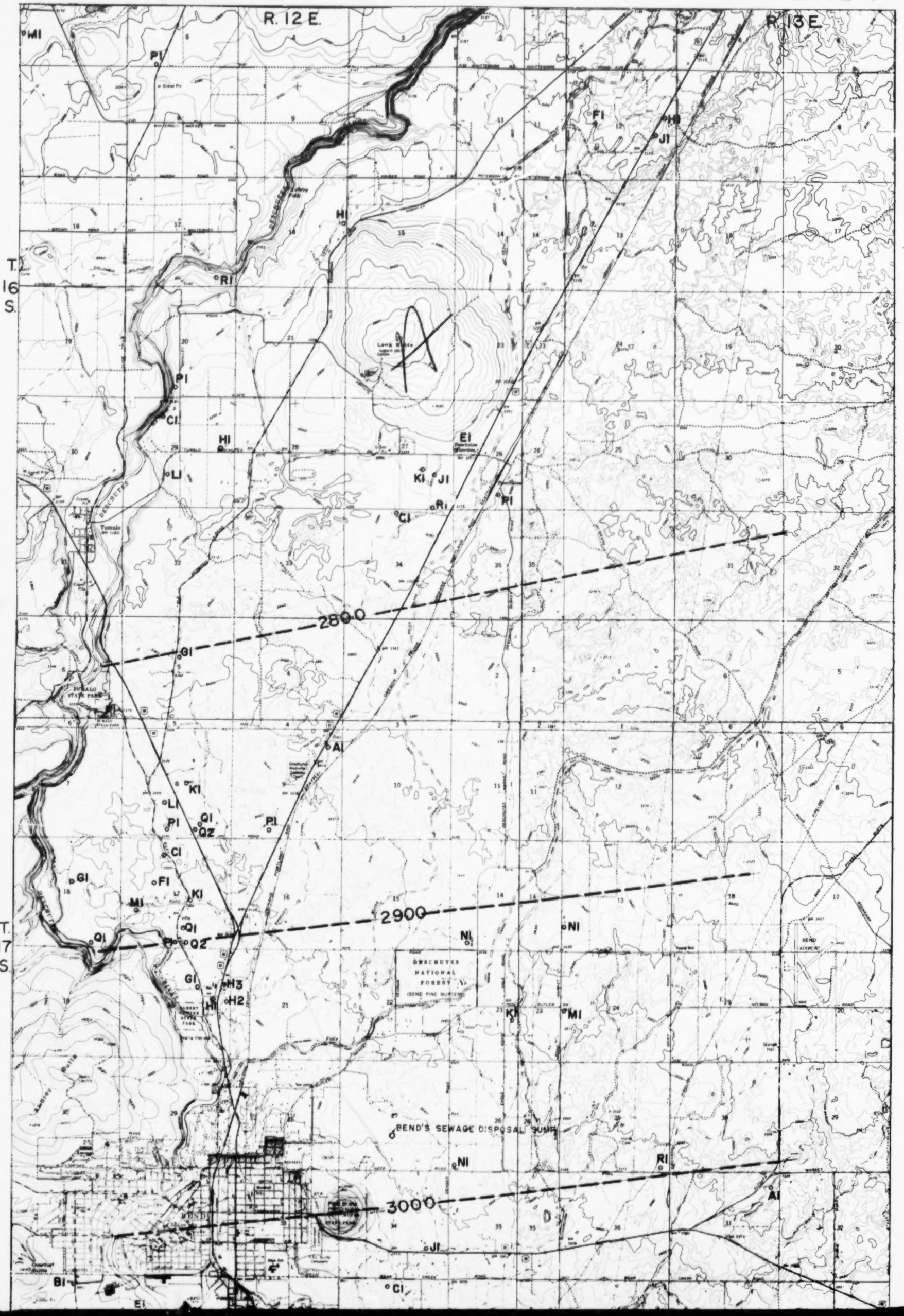
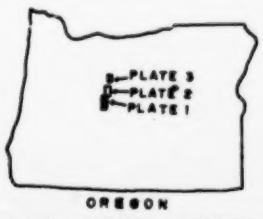
1900 CONTOUR SHOWING APPROXIMATE ALTITUDE OF THE REGIONAL WATER TABLE

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

PLATE I



MAP OF THE BEND AREA SHOWING THE LOCATION OF WELLS



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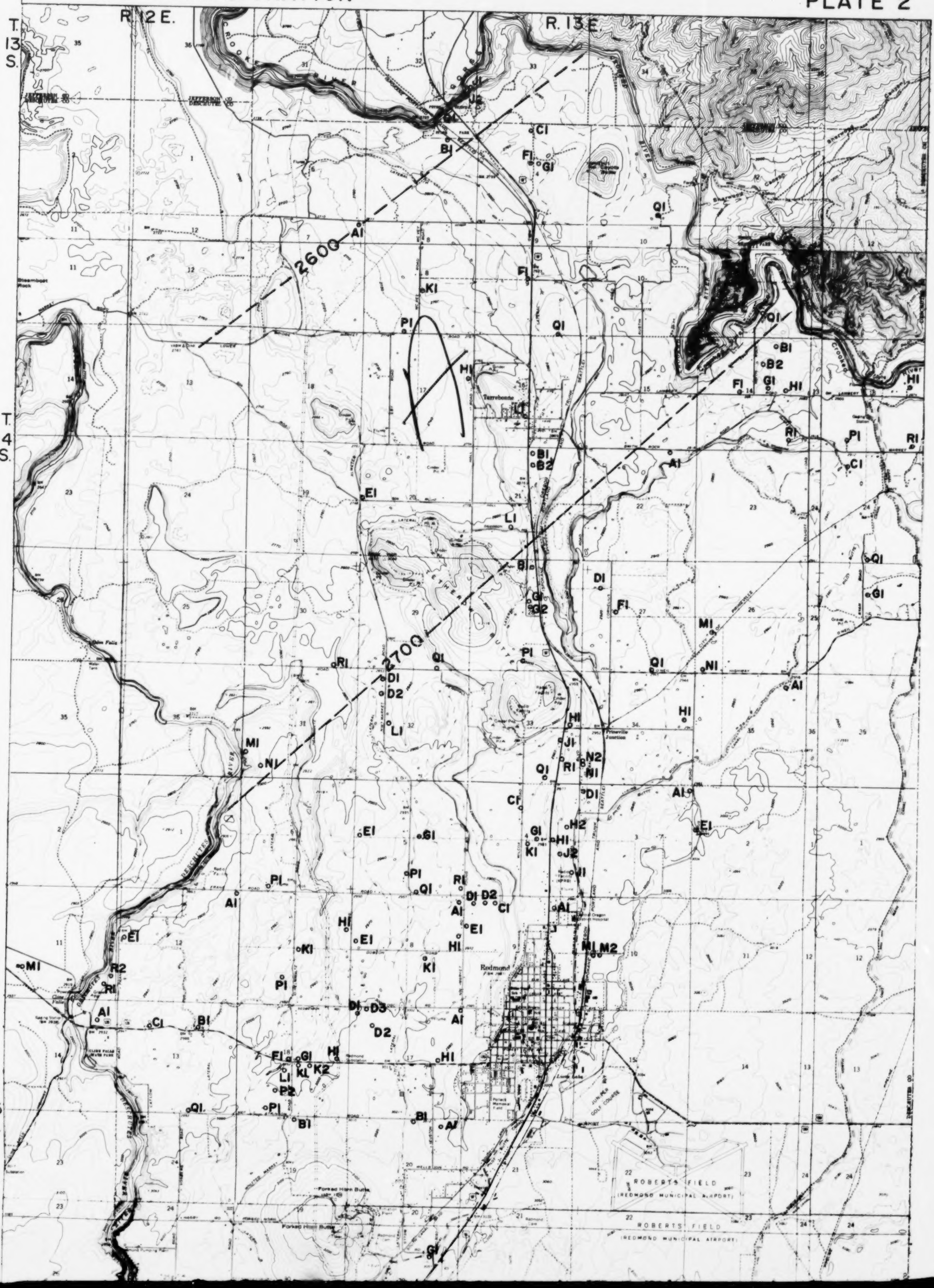
FEDERAL WATER POLLUTION
CONTROL ADMINISTRATION

PLATE 2



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Redmond

ROBERTS FIELD
(REDMOND MUNICIPAL AIRPORT)

MAP OF THE REDMOND AREA SHOWING THE LOCATION OF WELLS

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EXPLANATION

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